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Rice Stink Bug, Oebalus Pugnax (F.), on Rice: Evaluation for Plant Resistance, Interaction of Field Fungi With Feeding Damage, and Evaluation of Insecticides for Control.

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RICE STINK BUG, <u>OEBALUS PUGNAX</u> (F.), ON RICE: EVALUATION FOR PLANT RESISTANCE, INTERACTION OF FIELD FUNGI WITH FEEDING DAMAGE, AND EVALUATION OF INSECTICIDES FOR CONTROL

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University
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in partial fulfillment of the
requirements for the degree of

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in

The Department of Entomology

by

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B.S., University of Illinois, Urbana-Champaign, 1977
M.S., Purdue University, 1980
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Rice Stink Bug, *Oebalus pugnax* (F.), on Rice: Evaluation for Plant Resistance, Interaction of Field Fungi with Feeding Damage, and Evaluation of Insecticides for Control
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ABSTRACT

Feeding punctures of the rice stink bug (RSB), *Oebalus pugnax* (F.), provide fungi entry sites into rice, *Oryza sativa* (L.), grains and kernels (hulled grains). Feeding sheaths also serve as a source of nutrients for fungi.

Grain spotting fungi did not affect the percentage of spotted kernels (pecky rice) and significantly reduced full grain weight only at low infestation rates of one and two RSB per panicle. Panicles had been treated with a single application of propriconazol (1000 ppm) soon after flowering and later infested in the early milk stage with RSB adult pairs for 9 days. Propriconazol was not toxic to RSB adults. Infested rice lines were less susceptible to losses in full grain weight as panicles matured, but varied in the percentage of pecky kernels.

Reductions in the number of full grains in medium and long-grain rice lines can be estimated using a 9% saline solution. The highest average rate of misclassification was 13.8% and these grains were pecky and immature. Resistance to RSB in rice lines can be compared by infesting panicles in the early milk stage (about 10 days after

flowering) with three pairs of RSB adult pairs for 5 days. Either females, males, or pairs should be used consistently because females reduced the number of full grains more than males or pairs.

Fifty-seven rice breeding lines, predominantly from the 1982 and 1983 foliar disease nursery, were evaluated for resistance to RSB injury. Seventeen lines had less than a 26% reduction in number and/or weights of full grains.

The insecticides currently recommended for RSB control in Louisiana, encapsulated methyl parathion (0.3 kg AI/ ha), methyl parathion (0.3 kg AI/ ha), and Sevin XLR (1.1 kg AI/ ha), were re-evaluated. Encapsulation of methyl parathion extended activity for an additional day and this formulation was more toxic than methyl parathion to RSB in the first 24 hours of exposure. Carbaryl was active one day longer than the other insecticides, but all insecticides lost activity by 72 hours after application.

INTRODUCTION

Spotted kernels or "pecky rice" are often attributed to injury from the rice stink bug (RSB), *Oebalus pugnax* (F.) (Ingram 1927). Grain spotting fungi also discolor kernels (Douglas & Tullis 1950, Marchetti & Peterson 1984) and high percentages of pecky kernels have been found in harvested rice where both the insect and fungi were present (Ryker & Douglas 1938). Fungi are thought to sometimes enter kernels through RSB feeding wounds. Feeding punctures of RSB and associated fungi on rice grains and kernels were examined to determine whether feeding wounds facilitate infection.

The importance of RSB damage to reductions in yield and grain quality is difficult to assess because field fungi produce light-weight grain and pecky rice. A broad-spectrum fungicide which controls grain spotting fungi but is nontoxic to RSB was needed to carry out this evaluation. The toxicity of the fungicide, propriconazol, to field populations of RSB adult pairs was first tested. Then the effects of RSB adult pairs and endemic grain spotting fungi were determined on the weights of full grains and percent pecky kernels in rice panicles of 'Labelle', 'Saturn', and 'Starbonnet'. Susceptibility of panicles at different maturities to damage by RSB adult pairs was also studied.

Previous research has indicated that some rice lines may be more resistant to RSB damage than others (Swanson & Newsom 1962, Nilakhe 1976, Robinson et al. 1981). Unfortunately, techniques used to measure resistance are either unreliable or time consuming. A rapid method for assessing rice resistance to RSB was evaluated for accuracy. At the same time, resistance in some rice lines to RSB feeding injury was evaluated using a technique adapted from Robinson et al. (1980).

Though resistant rice cultivars are unavailable, several insecticides have been found that effectively control RSB populations (Bowling 1971, Oliver et al. 1972). The effectiveness of some of these insecticides has not been re-evaluated for more than a decade. The toxicity of an encapsulated formulation of methyl parathion, methyl parathion, and carbaryl to RSB adult pairs was evaluated.

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REVIEW OF LITERATURE

Taxonomic Nomenclature. In 1775, Fabricius first named the rice stink bug, *Cimex pugnax*. Other names included *Cimex typhoeus* Fabricius, 1803, *Pentatoma orthocantha* Palisot de Beauvois, 1805, *Pentatoma augur* Say, 1831, *Cimex vitripennis* Burmeister, 1835, *Mormidea typhoeus* (Fabricius) Dalles, 1851, *Pentatoma typhoeus* (Fabricius) Guerin-Meneville Sagra, 1857, *Oebalus typhoeus* (Fabricius) Stål, 1862, *Oebalus pugnax* (Fabricius) Stål, 1868; *Oebalus typhaeus* (Fabricius) Glover, 1876, *Pentatoma* (*Mormidea*) *typhaeus* (Fabricius) Stål, 1883, *Solubea pugnax* (Fabricius) Bergroth, 1891 (Sailer 1944).

Stål described the genus *Oebalus* in 1862. In 1891, Bergroth described the genus *Solubea* as a replacement name for *Oebalus*, because he thought it was preoccupied by *Oebalus* Rafinesque, 1815. However, Sailer (1957) reported that *Oebalus* Rafinesque was a *nomen nudum*, and thus *Oebalus* Stål was still the valid generic name.

Distribution. The rice stink bug is common in North America east of the Rocky Mountains (Sailer 1944), and occurs throughout Missouri, Arkansas, and Louisiana and along the coastal areas of Texas and Florida (Anon. 1975). The insect occurs to a lesser extent in the following 23 states: Wyoming, Oklahoma, Kansas, Iowa, Illinois, Indiana, Ohio, New York, Rhode Island, Conneticut, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia, Virginia, Tennessee, Kentucky, North Carolina, South Carolina, Georgia, Alabama and Mississippi (Davis 1925, Anon. 1975). Outside of the United States, the rice stink bug has been reported to occur in Cuba, the Dominican Republic (Bowling 1980), the

West Indies and the northern Gulf Coast region of Mexico (Sailer 1944).

Description of Life Stages. The adult rice stink bug averages from 1.0 to 1.3 cm in length and is longer than it is wide. The head, pronotum, and scutellum are straw yellow with a reddish cast. A sharp spine projects forward from each humerus of the pronotum. The antennae are pale red and the legs are yellow with scattered black punctures (Ingram 1927, Odglen & Warren 1962). Sailer (1944) developed a key to distinguish adult rice stink bugs from other species in the genus.

Mated females lay cylindrical eggs that are 0.86 mm long, 0.65 mm in diameter, and rounded at the base. The eggs are laid in groups of 10 to 47 that are arranged in two rows, so that the eggs in one row alternate with those in the other. The eggs are green when initially deposited and become red prior to hatching (Ingram 1927, Odglen & Warren 1962).

Newly hatched nymphs are round with a black head, thorax, legs and antennae. The abdomen is red with two black lines that run crosswise. As nymphs go through their immature stages, they become elongated and cream colored with red and black markings on the abdomen (Odglen & Warren 1962).

Life History. Unmated females and males overwinter in heavy bunch grasses near the ground's surface (Ingram 1927, Nilakhe 1976a) and in woodland trash (Odglen & Warren 1962). Primary overwintering sites include the stools of vasey grass, *Paspalum urvillei* Steud., broomsedge, *Andropogon* spp., and smut grass, *Sporobolus poiretti* (R & S) Hitch. (Nilakhe & Oliver 1974, Nilakhe 1976a). Adults generally emerge from these sites from April to early May (Ingram

1927, Odglen & Warren 1962, Nilakhe 1976a) with males appearing about 10 days earlier than females (Nilakhe 1976a). After 4 to 9 days, the females begin to lay eggs on the leaves and panicles of hosts (Ingram 1927, Odglen & Warren 1962, Nilakhe 1976a). In 3 to 11 days, the first instar nymphs hatch, remaining near their egg shells without feeding (Ingram 1927, Odglen & Warren 1962). The second instar searches for a feeding site, and after four additional molts during a 16 to 32 day period, nymphs develop into adults (Ingram 1927, Odglen & Warren 1962). The rice stink bugs feed throughout the day when the weather is sunny and not extremely hot. During heavy rains and/or high winds, the bugs remain on the lower portion of the plant for protection (Douglas 1939, 1942).

Female rice stink bugs live from 38 to 54 days, and the males from 28 to 42 days (Odglen & Warren 1962, Nilakhe 1976a). During the ovipositional period of 16 to 44 days, in which frequent matings occur ($\bar{X}$=34), from 73 to almost 500 eggs can be laid by a single female (Odglen & Warren 1962, Nilakhe 1976a). Two or three generations are produced on grasses before rice panicles emerge (Ingram 1927). One complete and three partial generations develop in rice fields by the time rice is harvested (Douglas 1939). Adults enter their hibernation quarters during October (Nilake 1976a).

As a food source, rice grains in the milk to dough stage are probably nutritionally superior to barnyardgrass and vasey grass. Females reared on rice produced almost twice as many eggs as on the other two grasses (Nilakhe 1976a). In choice tests, both sexes preferred rice panicles to vasey grass panicles (Naresh & Smith 1984). However, sorghum may be as good a host as rice for rice stink bug development (Naresh & Smith 1983).

Damage. Both adults and nymphs (except the first instar) feed on developing grains (Ingram 1927, Douglas 1939, 1942, Helm 1954a, Odglen & Warren 1962). Early in the season, they feed on a number of grass hosts found near and in rice fields (Douglas 1936). When panicles emerge, adults move to rice fields, where they prefer to feed on the milk to soft dough stages of the grain (Douglas 1936, Rolston et al. 1966). Helm (1954b) observed that rice which had reached the hard dough stage by 20 July, or had not developed to the milk stage by 20 September generally escaped major damage.

Two types of damage to rice kernels occur, depending upon the developmental stage of the grain when the rice stink bug begins to feed. Feeding during the milk stage often results in light-weight grain, while feeding during the dough stage produces "pecky rice" or "peck". Pecky rice consists of kernels with spots varying in shape, color, and size, from a pinpoint to one that encompasses the entire kernel (Ingram 1927, Douglas 1934, 1936, 1942, Douglas & Tullis 1950, Helm 1954b, Swanson & Newsom 1962, Rolston et al. 1966, Lee & Tugwell 1980). Discolored kernels also result after infection by grain spotting fungi such as *Bipolaris oryzae*, *Curvularia lunata* (Wakker) Boedijn, *Fusarium* spp., *Phoma* spp. and *Trichoconis caudata* (Appel and Strunk) Clements (Douglas & Tullis 1950, Marchetti and Peterson 1984). Punctures produced during feeding by the rice stink bug provide additional sites for fungal infection. (Ingram 1927, Douglas 1934, 1936, 1942, Ryker & Douglas 1938, Douglas & Ryker 1940, Douglas & Tullis 1950, Helm 1953, Odglen & Warren 1962, Lee & Tugwell 1980, Marchetti & Peterson 1984, Lee et al. 1984).

Rough rice yields are reduced when injury from rice stink bug feeding occurs in the milk stage. The resulting light-weight grain is discarded by the combine (Douglas 1934, Swanson & Newsom 1962, Rolston, et al. 1966, Fryar et al. 1986). Unfortunately, no recent estimates of the economic value for this type of injury exists for Louisiana. From 1930 to 1938, the average value of this loss was \$3,000,000 annually (Douglas & Tullis 1950). A recent Arkansas study concluded that for every 1% pecky rice in a brown rice sample, 1.4% of the grains are lost during harvest (Fryar et al. 1986).

Subsequent feeding in the dough stage by the rice stink bug can reduce the percentage of head rice and the grade (Swanson & Newsom 1962). During milling, pecky kernels break more easily than undamaged kernels, and spotted kernels are given a lower grade depending on their proportion to undamaged kernels (Douglas 1942, Douglas & Tullis 1950, Swanson & Newsom 1962, Bowling 1963). Based on an average of 2.7% peck, head rice yield is reduced by 3.8% (Brorsen et al. 1984). A loss of \$.77 per cwt is caused by the discount for peck and \$.39/ cwt is lost because of the lower yield of head rice. If the average yield is 116 cwt/ ha (USDA 1983), a loss of \$134.66/ ha occurs as a result of damage caused by rice stink bugs feeding during the dough stage (Brorsen et al. 1984).

Hosts. The rice stink bug feeds on the developing seed of a number of weedy and cultivated grasses besides rice. Economic hosts include corn, *Zea mays* L., wheat, *Triticum aestivum* L., barley, *Hordeum vulgare* L., rye, *Secale cereale* L., oats, *Avena sativa* L., and sorghum, *Sorghum vulgare* Pers. (Sailer 1944, Odglen & Warren 1962, McMilliam & Wiseman 1972, Hall & Teetes 1981).

Rice stink bugs also prefer sorghum panicles in the milk to soft dough stages. Feeding during these stages results in partially sterile panicles and/or shrunken grain and an overall reduction in seed weight (Dahms 1942, Hall & Teetes 1982a, 1982b). Wheat infested in the milk stage with only one pair of rice stink bugs per 20 spikes suffers a significant reduction in kernel weight. Other kinds of damage include a reduction in the percents germination, protein, and particle size index (Viator et al. 1983).

Rice stink bugs have been observed feeding on or have been collected from the following grasses in Texas: browntop brachiaria, *Brachiaria fasciculata* (S. W.) S. T. Blake; Texas millet, *Brachiaria texana* (Buck.) S. T. Blake; bermudagrass, *Cynodon dactylon* L.; *Digitaria sanguinalis* (L.) Scop.; barnyardgrass, *Echinochloa crusgalli* (L.) Beauv.; kleingrass, *Panicum coloratum* L.; *Panicum dichotomiflorum* (Michx.); dallisgrass, *Paspalum dilatatum* Poir.; *Panicum fasciculatum* Swartz; *Paspalum longipilum* Nash.; *Paspalum pubiflorum* Rupr. ex. Fourn.; *Paspalum urvillei* Steud.; *Phalaris minor* Retz.; johnsongrass, *Sorghum halepense* (L.) Pers. (Douglas 1939, 1942, Hall & Teetes 1981).

In Arkansas, Odglen & Warren (1962) observed rice stink bugs feeding on: *Corex* spp., *Digitaria* spp. *Echinochloa crusgalli* var. *mitis* (Pursh) Peterm., *Echinochloa crusgalli* (L.) Beauv. var. *crusgalli*, *Glyceria septentrionalis* Hitch., *Juncus effusus* L., *Panicum hians* Ell., *Paspalum dilatatum* Poir., *Paspalum distichum* L., *Rhynchospora inexpansa* (Michx.) Vahl., and *Sorghum halepense* L. Pers.

The following grasses and sedge found around Louisiana rice fields were tested for preference as a food source by rice stink bugs:

broadleaf signalgrass, Brachiaria platyphylla (Griseb) Nash.; bermudagrass, Cynodon dactylon (L.) Pers.; nutsedge, Cyperus iria (L.); southern crabgrass, Digitaria ciliaris (Retz); jungle rice, Echinochloa colonum (L.) Link.; goosegrass, Eleusine indica (L.) Gaertn.; red sprangletop, Letochloa filiformis (Lam.) Beauv.; Amazon sprangletop, Leptochloa panicoides (Persl.) Hitch.; dallisgrass, Paspalum dilatatum Poir.; bahiagrass, Paspalum notatum Flugge; vasey grass, Paspalum urvillei Steud.; yellow foxtail, Setaria glauca (L.) Beauv.; and johnsongrass, Sorghum halepense (L.) Pers. (Naresh & Smith 1984). Paspalum urvillei was preferred over all the other hosts, and confirmed an earlier observation in Texas (Douglas 1942).

Cultural Control. Many grasses around rice fields attract rice stink bugs and serve as breeding sites (Ingram 1927, Odglen & Warren 1962). Frequent mowing of these grasses prevents them from heading. Burning or plowing under the grasses in the fall can destroy hibernating bugs (Ingram 1927), but increases the opportunity for soil erosion (Douglas 1942).

Biological Control. Both predators and parasitoids help reduce the population of rice stink bugs. Eight birds, particularly the red-winged blackbird, Agelaius phoeniceus littoralis, are known to feed on the rice stink bug (Ingram 1927). Long horned grasshoppers of the genera, Conocephalus, Neoconocephalus, and Orchelimum readily feed on the eggs and first instar nymphs (Gifford et al. 1973, Nilakhe 1974, Nilakhe & Gifford 1974a). The nymphs, unlike the adults, do not have well developed scent glands and so are unable to protect themselves with defense secretions (Blum et al. 1960, Blum & Traynham 1962).

Third or subsequent nymphal instars and adults are parasitized by the tachinid flies, Baeskia aelops Walk. (Swanson 1960, Gifford et al. 1973, Nilakhe 1974, Nilakhe & Gifford 1974b), Gymnosoma spp. and Gymnoclytia spp. (Nilake 1974). Only a single larva develops in the abdomen of each rice stink bug. When mature, it exits through the dorsal cervical region and attaches itself to plant material above ground to pupate. The pupal period averages 7.5 days and ranges from 6 to 10 days. The parasite overwinters as a larva within hibernating rice stink bugs. Nilakhe and Oliver (1974) found 23% of the hibernating adults collected in a study to be parasitized. Parasitism of nonhibernating adults ranged from 1.4 to 15% (Swanson 1960, Nilakhe & Gifford 1974b).

Chemical Control. Monitoring of rice stink bug populations is important to determine whether chemical control measures are necessary. Sweep samples are often used to estimate populations and highly correlate with visual counts (Bowling 1969). Current recommendations in Louisiana are to treat with an insecticide when 50 rice stink bugs in 100 sweeps are collected during the first two weeks of heading, or 100 rice stink bugs are collected in 100 sweeps thereafter until two weeks before harvest. Four insecticides are recommended for control: malathion EC (0.6 kg AI/ ha), carbaryl WP (1.1-1.4 kg AI/ ha), methyl parathion (0.3 kg AI/ ha) and encapsulated methyl parathion (0.3 kg. AI/ ha)(Anon. 1986).

Additional insecticides have been evaluated in case the above mentioned insecticides become ineffective. Of the several insecticides screened using conventional and/or ultra low volume methods of application, monocrotophos EC (0.1 kg AI/ ha), dimethoate EC (0.1 kg AI/ ha) and carbofuran WP (0.3 kg AI/ ha) provided a level of control similar to the recommended insecticides (Brooks 1953, Helm 1954a, Bowling 1956, 1962, 1971, Everett 1962, Showers & Everett 1963, 1964, Showers et al. 1966, Oliver et al., 1971, 1972a, 1972b). Acephate (0.6 kg AI/ ha), and two formulations of carbaryl, Sevin XLR and Sevin XLR Plus (1.1 kg AI/ ha) controlled rice stink bugs for at least nine days (Way et al. 1986).

Plant Resistance. Early research indicated that some short or medium grain rice cultivars infested with rice stink bugs were damaged more than some of the long grain cultivars. The proportions of pecky kernels in the varieties, Zenith, Magnolia, and a selection from cross 44C507 were similar to one another, but were much higher than the proportions found in the long grain lines, Rexoro, Toro, Starbonnet, and 45C554 (Helm 1953, 1954a). Rice grade, which is partly determined by the percentage of pecky kernels, appeared to be more adversely affected by infestation in the medium grain cultivars, Magnolia, Nato, and Zenith than in the long grain cultivars, Bluebonnet 50 and Century Patna 231 (Swanson & Newsom 1962). Samples of medium grain cultivars taken at harvest over a two year period averaged almost four times more pecky kernels than long grain cultivars (Rolston et al. 1966).

Tolerance to rice stink bug feeding damage was evaluated in 228 breeding lines from the 1973 Arkansas disease nursery. Two nymphs less than a day old were caged on a panicle and were allowed to feed until 10 to 14 days after they had become adults. Comparisons made between uninfested and infested panicles within an entry indicated that 26 lines, including the ten commercial cultivars, Northrose, Vista, Bluebelle, Saturn, Labelle, Starbonnet, Nova 66, Dawn and Zenith, did not differ significantly in weight loss per grain (1.4-9.5 mg/ grain). Unfortunately, all entries had high percentages of pecky kernels, though the 71% pecky kernels in the lines Stg 70L1188 and Stg 70L1217 was significantly lower than the other lines (Nilakhe 1976b). In a choice test using nine world collection lines and Saturn, WC 1123 had significantly less damaged kernels (4.4%) than Saturn (11.4%) (Latson et al. 1976).

Rice stink bug adults confined to panicles of 'Vista' and irradiated 'Brazos' at densities of 0, 1, 2, 3, 4, and 5 pairs per panicle for 7 to 8 days affected the percentage of full grains. Panicles infested with three pairs of adults per panicle had significantly less percent full grains than uninfested panicles (Robinson et al. 1980). Using this infestation rate, 32 uniform rice nursery breeding lines were evaluated for resistance to rice stink bug damage. Line RU 7603015 did not differ significantly from the uninfested panicle with respect to the percentages of unfilled florets (sterile spikelets), pecky kernels and damaged grain. Infested panicles of RU 7403025 and a selection from bulk TTEP crosses also had less than 45% damaged grain (Robinson et al. 1981).

While most studies included some measurement of damage to rice in their screening of lines or varieties for resistance to rice stink bugs, the number of feeding sheaths (flanges) produced by the rice stink bug during feeding has also been used as a criterion for detecting resistance (Bowling 1979, Smith et al. 1979). In a laboratory screening of 106 breeding lines and cultivars, early maturing cultivars in Group I had almost twice the number of feeding sheaths as the late maturing Group IV cultivars (Smith et al. 1979).

The antibiotic effect of different rice breeding lines and cultivars, as measured by the duration of the nymphal period of the rice stink bug, has also been used as a screening technique, but inconsistent results are obtained when temperature fluctuates during the test period. Nymphs reared on the lines, PI 247949, CI 8292, CI 8927 and PI 242804, required 4 to 6 days longer to develop into adults than the nymphs reared on 'Starbonnet'. The nymphal period of rice stink bugs on PI 202994 was 4 days longer than on 'Saturn' (Nilakhe 1976b).

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CHAPTER I

STRUCTURE AND FORMATION OF FEEDING SHEATHS OF THE RICE STINK BUG (HEMIPTERA: PENTATOMIDAE) ON RICE GRAIN AND THEIR ASSOCIATION WITH FUNGI

This chapter is written in the style of the
Annals of the Entomological Society of America

ABSTRACT

Examinations of feeding sheaths and wound sites produced by the rice stink bug, Oebalus pugnax (F.), on grains and kernels (dehulled grains) of rice, Oryza sativa L., were used to determine their association with grain spotting fungi. Scanning electron micrographs of rice grains infested with O. pugnax showed that presence of a sheath did not necessarily indicate successful penetration of the hull. Sheaths produced during feeding were predominantly open, allowing fungi to enter. Fungi were found growing in the sheath openings, in the interior, and on the exterior walls of sheaths. Fungi were also found around wound sites on the undersides of hulls and at wound sites on the surface of kernels. These observations indicate that pathogenic or weakly pathogenic fungi may use sheaths and feeding wounds produced by O. pugnax to penetrate rice hulls and damage kernels, thereby increasing the incidence of "pecky" or low-quality rice.

INTRODUCTION

Rice stink bugs, Oebalus pugnax (F.), feed on grains of rice, Oryza sativa L., when they are in the milk to soft dough stages (Douglas 1936, Rolston et al. 1966). Feeding during the milk stage often results in empty glumes, while later feeding produces discolored lesions on kernels (dehulled grains), a condition known as "pecky" rice (Douglas & Tullis 1950, Swanson & Newsom 1962). These grains, when milled, either result in darkly spotted polished rice, or an increased percentage of broken rice kernels because of their weakened structure. Specific causes for pecky rice have not been determined, but are thought to be due primarily to *O. pugnax* or various fungi or both (Bowling 1963, Douglas & Tullis 1950, Lee & Tugwell 1980, Marchetti & Peterson 1984). Parasitic fungi like *Fusarium* spp., *Curvularia lunata* (Wakker) Boedijn, *Bipolaris oryzae* (Breda de Haan) Shoem., *Cercospora oryzae* Mij, and *Trichonis caudata* (Appel and Strunk) Clements, can enter grain directly from spots on the hull (Douglas & Tullis 1950). With respect to the association of *O. pugnax* with pecky rice, kernel damage may be the result of insect feeding, fungi introduced during feeding, or subsequent entry of parasitic or weakly parasitic fungi into the feeding puncture.

During feeding, *O. pugnax* salivates and produces a feeding sheath (flange or collar [Miles 1967, 1968]) on the grain surface (Bowling 1979). The stylets push through the solidifying material into the tissue below, forming a cone-shaped structure. Although sheath formation by *O. pugnax* has not been studied, it is probably similar to that of other seed-feeding Hemiptera, like *Oncopeltus fasciatus* (Dallas) (Miles 1958, 1959). These sheaths remain on the plant surface after the stylets have been withdrawn.

Little information is available on the relationship between feeding by *O. pugnax* and fungi that damage kernels. Our study shows the association between fungi, and feeding sheaths and wounds produced by *O. pugnax*.

METHODS AND MATERIALS

Mature rice panicles previously infested by caging with field-collected adult pairs of *O. pugnax* were collected in July and

August 1980, from plants grown in the field at the Rice Research Station, Crowley, La. Each panicle was placed in a plastic bag and stored at 4°C until examination.

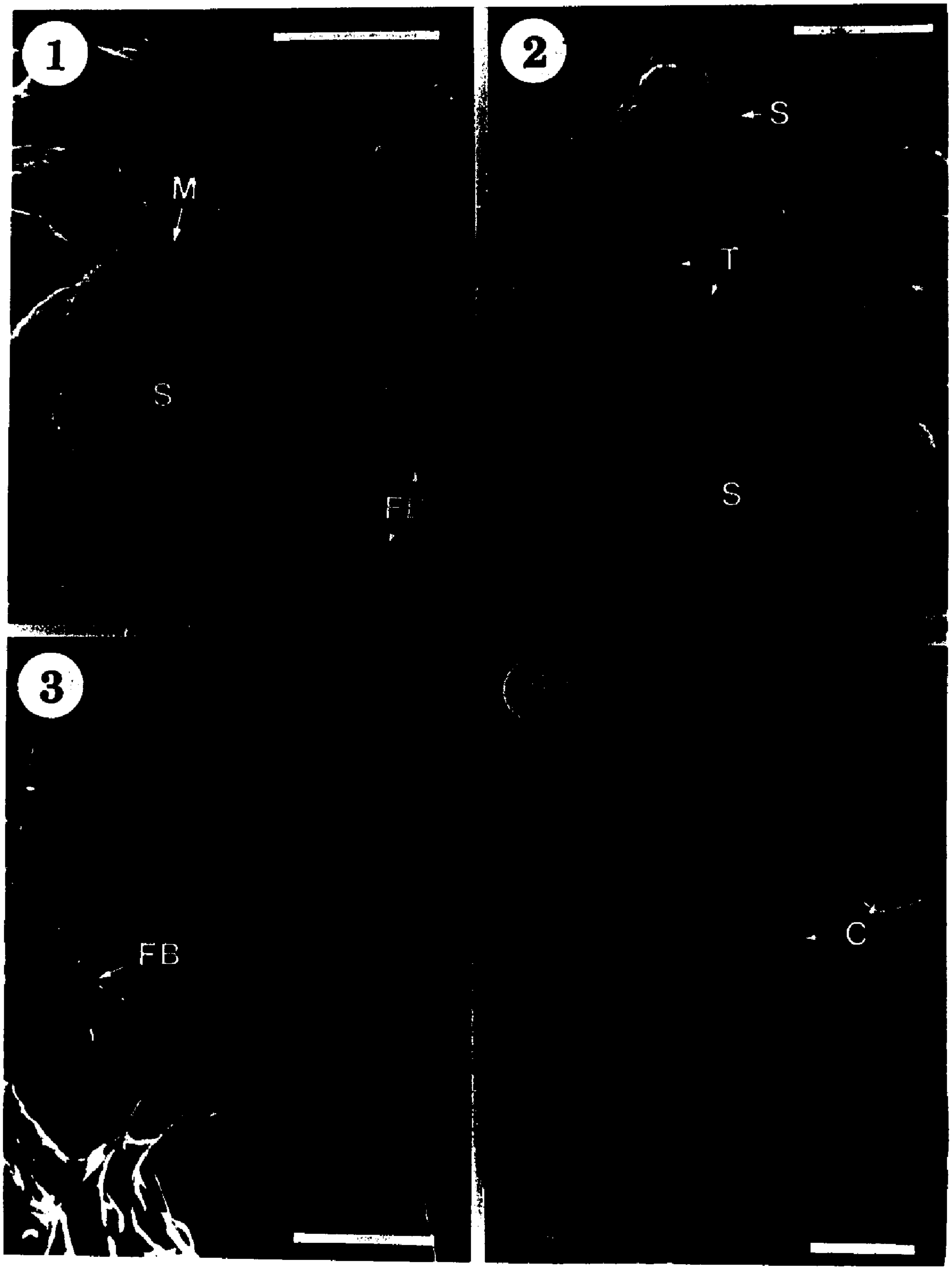
Air-dried 'Calrose,' 'Early Wataribune,' 'Bluebonnet,' 'Labelle,' and 'Saturn' rice grains were examined for feeding sheaths at 10X. Sheaths were removed with a dissecting needle and grains were dehulled by pulling the lemma and palea apart.

Rice grains, hulls, and kernels were mounted on 13-mm-diameter aluminum Cambridge stubs with television tube coat, sputter-coated with 20-40 nm of gold palladium (Hummer I sputter coater and Edwards S 150 sputter coater) and examined with a Hitachi S-500 scanning electron microscope. Photographs were taken using a Polaroid camera attached to the microscope and Kodak Tri-X Ortho film.

RESULTS AND DISCUSSION

Feeding sheaths of O. pugnax are cone-shaped and vary in size. Smaller sheaths (approximately 50 μm basal diameter) may have resulted from exploratory feeding probes whereas larger ones (approximately 250 μm basal diameter) were probably produced after feeding for a prolonged period. Counts of feeding sheaths have been used for measuring rice resistance to rice stink bugs (Bowling 1979) and to detect damage to wheat seed (Viator et al. 1983). However, sheaths were found below the resolution of the dissecting microscope (30X) and were difficult to detect even after acid fuchsin staining. Sheaths are both open and closed (Fig. 1 and 2). Open sheaths often occur singly and sometimes in pairs (Fig. 1), whereas closed sheaths are often found in groups of two or more (Fig. 2). Open sheaths may be

Fig. 1-4 Scanning electron micrograph of opened and closed feeding sheaths of O. pugnax and their associated fungi. 1. Mycelium (M) and Cladosporium sp. fruiting bodies (FB) on the outer wall of an opened sheath (S). Bar = 50μm. 2. Two closed sheaths (S) with elongated tips (T) on a 'Labelle' rice hull. Bar = 50μm. 3. Mycelia and Cladosporium sp. fruiting bodies (FB) on the outer wall and at the tip of a sheath. Bar = 50μm. 4. Conidia (C) near and inside the opening of a sheath on a 'Saturn' grain. Bar = 5μm.


1
M
S
FB
2
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FB
C

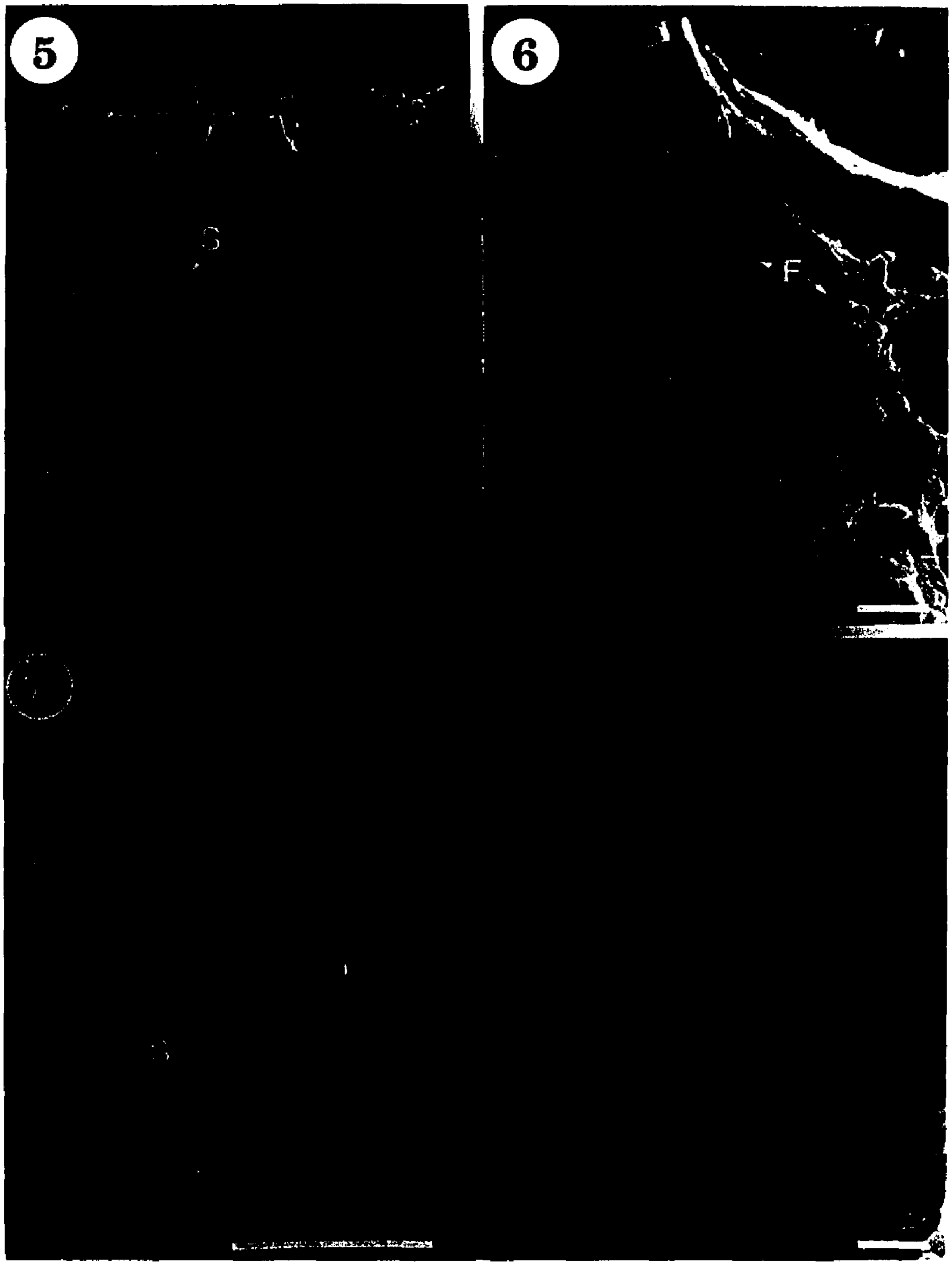
the result of rapid stylet withdrawal by O. pugnax upon disturbance. Uninterrupted feeding allows O. pugnax to withdraw their stylets slowly and, at the same time, to form the long thin sheath tips while the sheath material is still soft.

Fungi were found in close association with both open and closed sheaths. Mycelia and Cladosporium sp. fruiting bodies were observed along the outer walls of open and closed sheaths (Fig. 1 and 3). Fungi probably use the sheaths as a nutritive substrate, because abundant fruiting bodies were often seen. The feeding sheaths formed by O. fasciatus are composed primarily of lipid-associated proteins, containing tyrosine and some tryptophan (Miles 1960).

Unidentified fungal conidia and mycelia were also located near and inside the tips of open sheaths (Fig. 4), as well as on the inside basal surface and opening of a dislodged sheath (Fig. 5 and 6). During sheath formation the soft salivary material flows outward. After hardening, the surface of the basal area of the sheath acquires the mirror image of the rice hull below. This reticulation provides an important mechanism for adhesion of the sheath to the hull. Extensive mycelial growth on the inside basal surface of the dislodged sheath indicates that fungi either enter through the opened tip or in the space between the hull and sheath.

Examination of the grain under a removed sheath showed that not all feeding attempts by O. pugnax result in successful penetration of the the rice hull by the stylets (Fig. 7). This observation is supported by the fact that in natural infestations, only 42% of rice grains with feeding sheaths were pecky (Marchetti & Peterson 1984).

Fig. 5-8. Feeding sheaths and stylet penetration into the rice hull. 5. Dislodged sheath (S) on a 'Labelle' grain surrounded by mycelia. Bar = 50µm. 6. Magnified view of fungi (F) around basal opening of dislodged sheath (S) in Fig. 5. Bar = 5µm. 7. Unsuccessful stylet penetration of a 'Labelle' hull (H). Remnants of the removed sheath (S) remain. Bar = 50µm. 8. Hole in 'Labelle' hull resulting from stylet penetration. Bar = 50µm.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6
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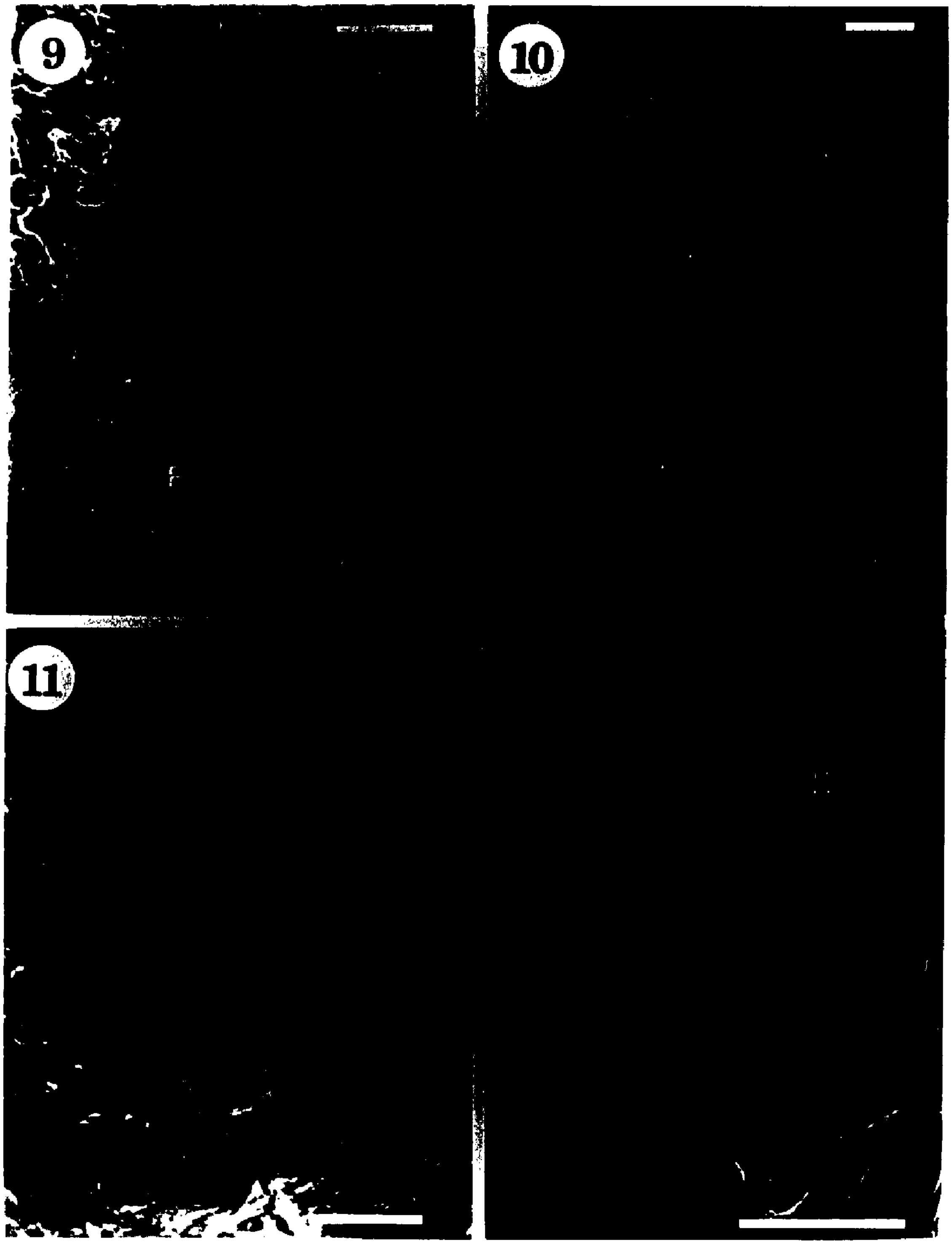
Where successful stylet penetration of the hull occurred (Fig. 8), fungi were observed on the underside of the hull and in and around feeding wounds (Fig. 9 and 10). However, stylet penetration through the hull did not always result in the successful penetration into the kernel below (Fig. 11). That fungal mycelia occur only within the feeding wound of a kernel (Fig. 12) indicates that fungi are carried on or in the stylets of *O. pugnax* at feeding or that they enter the open wound after feeding.

Fig. 9-12. Fungi associated with punctures beneath the rice hull and in the kernel. 9. Fungi (F) around puncture (P) on the underside of a 'Bluebelle' hull. Bar = 50μm. 10. Fungal fruiting bodies (FB) in and around puncture (P) in Fig. 9. Bar = 5μm. 11. Unsuccessful penetration into a 'Labelle' kernel. A slight indentation of the kernel surface is shown. Bar = 50μm. 12. Mycelia (M) associated only with a puncture on a 'Labelle' kernel (K). Bar = 50μm.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CHAPTER II

TOXICITY OF THE FUNGICIDE PROPRICONAZOL TO RICE STINK BUG ADULTS

This chapter is written in the style of the
Journal of Economic Entomology

ABSTRACT

The fungicide propriconazol controls foliar pathogens of rice, *Oryza sativa* (L.), which are known to cause grain spotting. Propriconazol solutions from 0 (water) to 10000 ppm were tested for toxicity to rice stink bug (RSB), *Oebalus pugnax* (F.), adult pairs in the field. The highest concentration was also tested in the laboratory. Cumulative mortality in the field ranged from 0.0 to 8.0% after 120 hours exposure to treated panicles. None of the propriconazol treatments increased RSB mortality compared to the untreated control. In the laboratory test, cumulative mortality after exposure to panicles treated with 10,000 ppm propriconazol was not different from water-treated panicles. Males had 20% higher mortality than females.

INTRODUCTION

The rice stink bug (RSB), *Oebalus pugnax* (F.) feeds on developing rice grains. Grains damaged early in development abort or fail to fill. Grains fed upon in the soft dough and later stages often result in discolored kernels (dehulled grains) referred to as "pecky rice". Lesions found on pecky kernels are often circular with a small dark spot (feeding puncture) surrounded by a relatively large white chalky area (Douglas & Tullis 1950, Lee & Tugwell 1980). Some field fungi discolor kernels and may use feeding wounds from RSB as entry sites into kernels (Marchetti & Peterson 1984).

The broad-spectrum fungicide, propriconazol (Tilt 3.6 EC), was used to determine the amount of kernel damage attributable to RSB alone and in conjunction with naturally occurring field fungi (Chapters III & IV). However, it was first necessary to determine the toxicity of propriconazol to RSB adults.

METHODS AND MATERIALS

Field test. When 'Saturn' panicles were in the 50% bloom stage on 30 July 1982, random panicles were sprayed using a 0.5-liter plastic hand-held spray bottle with 0 (water), 1000, 2500, 5000, 7500 and 10,000 ppm solution of propriconazol. Panicles were sprayed until run-off (10 squirts) and allowed to dry for 2 hours. Five copulating pairs of field-collected RSB adults were infested on each panicle. Mortality counts were taken every 24 hours until 120 hours after infestation.

There were two blocks and each treatment was replicated three times within a block. Cumulative mortality at 120 hours was expressed as a percentage of the 10 adults caged on a panicle and analyzed using GLM (SAS Institute 1982). Means were separated using Duncan's multiple range test (SAS Institute 1982).

Laboratory test. On 3 August 1982, field-grown 'Saturn' panicles in the soft dough stage were brought to the laboratory and dipped in water or a 10,000 ppm propriconazol solution. Panicles were placed on paper towels and air-dried. Two similarly treated panicles were placed in a 250-ml glass jar along with five RSB adult pairs hand-collected from headed rice and grasses. The jar was covered with two layers of cheese cloth and secured with a rubber band. Three ml of tap water were added to each jar at the end of the 24 and 48-hour mortality reading.

Each fungicide treatment was replicated five times. Cumulative mortality at 24, 48 and 96 hours for each sex was expressed as a percentage of the initial number of bugs placed in the jar. Data were analyzed and means were separated as in the above test.

RESULTS

Field test. A 1000 ppm (1.0%) propriconazol solution is the recommended rate of application for commercial rice production (M. C. Rush, Dept. of Plant Pathology and Crop Physiology, Louisiana Agric. Exp. Stn., Louisiana State Univ. Agric. Center, personal communication). No differences ($P > 0.40$) were detected in the percent mortality of RSB adults exposed for 120 hours to varying concentrations of propriconazol (Appendix A, Table A1). Average mortality ranged from 0% (1000 ppm) to 8.3% ± 3.1 (± SE)(2500 ppm) (Table 1).

Laboratory test. Only the highest concentration used in the field test was evaluated. Significant differences ($P < 0.05$) in the percent mortality of RSB adults were detected depending on the time of the mortality reading and the sex of the insects tested (Appendix A, Table A2). Mortality increased as time progressed. The average 24-hour mortality across sex and propriconazol concentrations was 12.5% (± 2.9, n=24) and was significantly lower ($P < 0.05$) than the 96-hour mortality of 23.3% (± 3.3, n=24). Forty-eight hours after initial exposure, RSB mortality (16.7% ± 3.3, n=24) was almost 4% higher than at 24 hours but was not significantly different ($P > 0.05$). Mortality of RSB exposed to untreated 'Saturn' was almost

Table 1. Average cumulative percent mortality of field-collected rice stink bug (RSB) adult pairs caged for 120 hours on Saturn rice panicles previously treated with the fungicide propriconazol. Crowley, LA, 1982.

Propriconazol (ppm)[a]	n	Cumulative % mortality[b] ($\bar{X} \pm SE$)
0	5	8.0 ± 3.7
1000	6	0
2500	6	8.3 ± 3.1
5000	6	6.7 ± 3.3
7500	6	3.3 ± 2.1
10000	6	6.7 ± 3.3
$\bar{X} \pm SE$		5.4 ± 1.2

[a] Concentrations are equivalent to 1.0, 2.5, 5.0, 7.5 and 10.0% aqueous solutions of commercial product, respectively.

[b] Each mean is an average of the percent mortality of the 10 RSB caged on each panicle (experimental unit). Sixty insects (30 pairs) were exposed to each concentration except for the control.

20% when averaged across sex and time and was not different ($P > 0.05$) from the mortality of insects exposed to panicles treated with 10,000 ppm propriconazol (16.1%) (Table 2). When averaged across propriconazol concentrations and time, the mortality of female RSB was almost 20% less ($P < 0.05$) than that observed for males (Table 2).

DISCUSSION

A single application of the fungicide, propriconazol, at concentrations up to ten times the recommended rate for commercial application was found to have no adverse effects on short-term longevity of field-collected copulating pairs of RSB adults. Insects were confined to panicles as early as 2 hours after propriconazol application. Higher mortality among males compared to that of females was observed in both untreated and treated panicles in the laboratory. Under normal conditions, males generally live a shorter time than females (Nilake 1976).

Because good control of rice diseases often involves multiple applications of fungicide (Marchetti & Peterson 1984), the toxicity of a fungicide to RSB should also be tested by topical application of the solution to the insect. The sex of the insect must also be considered. Males weigh less than females and may appear more susceptible because the dosage is actually higher.

Table 2. Average cumulative percent mortality of field-collected rice stink bug (RSB) adult pairs on Saturn rice panicles treated with propriconazol[a]. Crowley, LA, 1982.

	Cumulative % RSB mortality ($\bar{X} \pm SE$)				
Propriconazol (ppm)	n	Females	n	Males	$\bar{X} \pm SE$
0	18	6.7 ± 2.8	18	31.1 ± 3.7	19.9 ± 3.1 a
10000	18	8.9 ± 2.4	18	23.3 ± 2.9	16.1 ± 2.2 a
$\bar{X} \pm SE$		7.8 ± 1.8 a		27.2 ± 2.4 b	

Means in the margin of a column or row followed by the same letter are not significantly different, $P > 0.05$, Duncan's multiple range test (SAS Institute 1982). $P < 0.08$ for the interaction between sex and propriconazol concentration.

[a] Cumulative mortality was taken 24, 48 and 96 hours after introduction of 5 pairs of RSB adults into 250-ml glass jars containing two similarly treated panicles.

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CHAPTER III

THE EFFECTS OF RICE STINK BUG (HEMIPTERA: PENTATOMIDAE), GRAIN SPOTTING FUNGI AND PANICLE AGE ON FULL GRAIN WEIGHT AND PECKY KERNELS IN RICE

This chapter is written in the style of the
Journal of Economic Entomology

ABSTRACT

Feeding by the rice stink bug (RSB), Oebalus pugnax (F.) prevented the development of full grains and increased the number of spotted (pecky) kernels among full grains. The amount and type of damage also varied with the rice line and panicle maturity at the time of infestation. As panicles matured, grains were less susceptible to reduction in full grain weight. One and two RSB adult pairs per panicle decreased the weight of full grains by 20 and 40% compared to uninfested panicles when panicles were infested in the early milk stage for 9 days. A single application of the broad spectrum fungicide, propriconazol, did not reduce the percentage of pecky kernels in infested panicles. However, full grain weights were significantly increased in propriconazol-treated panicles at low infestation rates of one and two RSB adult pairs per panicle. Under these conditions, propriconazol appeared to suppress development of fungi associated with RSB injury.

INTRODUCTION

Feeding injury by rice stink bug (RSB), Oebalus pugnax (F.), adults and nymphs to developing rice, Oryza sativa L., grains results in light-weight grains and spotted (pecky) kernels (Douglas & Tullis 1950, Swanson & Newsom 1962). Head (unbroken) rice yields are reduced because light-weight grains are lost during harvest and pecky kernels often break during milling. Rough rice samples containing 0.5% or more pecky kernels receive a poorer quality grade and a lower price per cwt. (USDA 1977).

Light-weight grains and pecky kernels also result from infection by endemic grain spotting fungi such as Bipolaris spp. and Curvularia spp. (Douglas & Tullis 1950, Lee & Tugwell 1980, Marchetti & Peterson 1984). In the experiments summarized here, we investigated the effects of RSB injury and endemic grain spotting fungi on yield loss and pecky kernel production, and the susceptibility of rice panicles at different maturity stages to RSB injury.

METHODS AND MATERIALS

Rice stink bug density - fungicide test. The rice cultivars, Labelle, Saturn and Starbonnet, were planted on 24 May 1982 and 31 May 1983 in a randomized complete block design (1982, four blocks; 1983, three blocks). Seeds of each cultivar were drill-seeded in 2-m rows spaced 0.5 m apart using a drop cone planter. The herbicides, propanil (4 EC) and thiobencarb (8 EC) were applied at a rate of 3.3 kg AI/ ha ca. 3 weeks after planting. Granular fertilizer was applied once each year prior to permanent flood (23 June 1982 and 7 July 1983) at a rate of 112 kg N, 56 kg P_2O_5 and 56 kg K_2O per hectare. Carbofuran was applied post-flood at 0.5 kg AI/ ha for rice water weevil, Lissorhoptrus oryzophilus Kuschel, control.

To control endemic grain spotting fungi, random panicles within a row were sprayed until run-off with a 1000 ppm solution of propriconazol (Tilt 3.6 EC) using a 0.5-liter hand-held air-pump sprayer. Panicles were treated near the completion of flowering to minimize possible interference with fertilization.

RSB adult pairs were hand-collected from headed grasses, primarily vasey grass, Paspalum urvillei Steudel, and placed in polyetheylene bags. Only copulating pairs were collected to obtain a somewhat uniform group of insects since their chronological ages were unknown. Collected insects were chilled for 2 min at 4 °C, sorted by sex into groups of 20 to 60 insects and placed in polyethylene bags containing vasey grass or rice panicles and water-moistened paper towels. The insects were held at room temperature (ca. 24 °C) and used for infestations within 2 days of collection. Nylon tulle cages (30.5 cm long, 7.5 cm wide and 64 openings/cm^2) were used for confining insects on rice panicles. To facilitate replacing dead insects during the infestation period, one corner of the cage was left unsewn and was pinched closed with a 3.8-cm length of twist-tie.

Panicles were infested when apical grains were in the early milk stage. One or two grains near the top were squeezed to indicate the approximate age of the panicle. RSB (0, 1, 2, 3, 4 and 5 pairs) were caged on a panicle and were allowed to feed for 9 days. Infested panicles were checked every other day for mortality, and dead insects were replaced with live ones of the appropriate gender. At the end of the infestation period, the test insects were decapitated. Cages remained on panicles to discourage feeding by RSB naturally present in plots.

At maturity, panicles were harvested (25 September 1982 and 6 October 1983), cages were removed and panicles were stored in paper envelopes at -4 °C. For evaluation, frozen panicles were thawed at room temperature (ca. 21 °C) for 2 days and then dried at 42 °C for an additional 2 days in a drying oven (Precision Scientific Model 8). Individual panicles were hand-threshed and were allowed to equilibrate at room temperature (ca. 22 °C) for at least 2 weeks before processing. The grains in a single panicle were mixed with a 9% saline solution (reagent grade NaCl and distilled water) in a 250-ml beaker. Floating grains were removed with a perforated plastic spoon. Sinking (full) grains were rinsed under tap water, placed between two layers of filter paper in 90-mm glass petri-dish bottoms, dried in a microwave oven (Panasonic Model NE-8030) for 45 sec at medium heat, cooled for at least 10 min and weighed.

To determine the percent pecky kernels among full grains in a panicle, the full grains were hand-hulled and the number of spotted kernels counted. In 1982, panicles infested at all RSB densities tested were evaluated for pecky kernels. Because this step was so time consuming, only uninfested-caged panicles and panicles infested with three pairs of RSB adult pairs per panicle were evaluated in 1983.

For analyses, all percentage data were transformed by taking the arcsine square root. Weight (1982 and 1983) and percent pecky kernel (1982) data were analyzed using the General Linear Models Procedure (SAS Institue 1982) as a randomized complete block design with three factors: six levels of RSB density, two levels of fungicide treatment and three rice cultivars. Each treatment combination was replicated two or three times. Significant ($P < 0.05$) main effects and simple interactions were examined using Duncan's multiple range test (SAS Institute 1982).

The percent pecky kernel data in 1983 were combined with data of the same treatments in 1982 and analyzed as a randomized complete block design with two levels of RSB density, two levels of fungicide treatment and three rice cultivars. Signficant main effects and interactions were examined as above.

Panicle Age - Duration of Infestation Test. Two rice cultivars, Labelle and Saturn, and two breeding lines (hereafter collectively called lines), Stg 70L1188 and Stg 70L1217 were planted on 8 June 1982 and 31 May 1983. Seeds of each line were planted in a randomized complete block design (1982, five blocks; 1983, three blocks), fertilized, and treated for weeds and rice water weevil larvae as in the above test. Beginning 2 July 1982 and 7 July 1983, a permanent flood of 10 to 15 cm was maintained until harvest.

Panicles were tagged to determine panicle age as anthers of the apical grains were visible (Day 0). On days 0, 10 and 20, panicles were caged with 0 or 3 RSB adult pairs as described previously. The insects were allowed to feed for 5 and 10 days on panicles of each age. Mortality was checked and the infestation was terminated as described above. Panicles were processed using the method previously described. All treatments of both years were evaluated.

Analysis of variance was calculated and means were separated as in the first experiment. To simplify computer analysis, the infestation rate was multiplied by the duration of infestation to obtain 0, 30 and 60 "bug days". Results were averaged over both years and analyzed as a randomized complete block design with three factors: three levels of bug days, three levels of panicle age and four rice lines.

RESULTS

Rice stink bug density - fungicide test. Full grain weights per panicle declined ($P < 0.05$) as infestation rates increased to five RSB adult pairs per panicle (Table 1; Appendix B, Table B1). The largest

Table 1. Weight of full grains[a] in rice panicles treated with the fungicide propriconazol and later infested with different densities of rice stink bugs. Crowley, LA, 1982 and 1983.

	Full grain wt. (g)/ panicle ($\bar{X}$ ± SE)				
Adult prs./ panicle	n	Untreated	n	1000 ppm propriconazol	$\bar{X}$ ± SE
0[b]	41	2.2 ± 0.1 A	37	2.9 ± 0.1 B	2.5 ± 0.1 a
1	39	1.7 ± 0.1 A	39	2.2 ± 0.1 B	1.9 ± 0.1 b
2	41	1.3 ± 0.1 A	41	1.8 ± 0.1 B	1.5 ± 0.1 c
3	40	1.3 ± 0.1 A	41	1.1 ± 0.1 A	1.2 ± 0.1 d
4	39	0.9 ± 0.1 A	41	1.0 ± 0.1 A	0.9 ± 0.1 e
5	41	0.7 ± 0.1 A	39	0.9 ± 0.1 A	0.8 ± 0.1 e
$\bar{X}$ ± SE		1.5 ± 0.1 a		1.8 ± 0.1 b	

Fungicide treatment means across density treatments in a row or density means across fungicide treatments in a column followed by the same lower case letter are not significantly different at the P > 0.05 level as determined by Duncan's multiple range test. Means within a density in a row followed by the same upper case letter are not significantly different at the P > 0.05 level as determined by Duncan's multiple range test (SAS Institute 1982).

[a] Grains in a panicle that sank in 9% saline solution.

[b] Caged.

weight loss occurred at the lower infestation rates. Panicles infested with one pair of RSB adults averaged 24% less ($P < 0.05$) weight than uninfested-caged panicles. When the infestation rate doubled, panicles averaged 40% less ($P < 0.05$) weight than the control. At infestation rates of four and five RSB adult pairs per panicle, panicle weights remained relatively unchanged ($P > 0.05$).

Treatment of panicles with a single application of a 1000 ppm solution of the fungicide, propriconazol, increased ($P < 0.05$) the weights of full grains in uninfested panicles and panicles infested with one and two RSB adult pairs compared to similarly infested panicles not treated with fungicide (Table 1; Appendix B, Table B1). No differences ($P > 0.05$) in weights were found between the two groups of panicles infested with three, four or five RSB pairs per panicle.

When averaged over fungicide treatments and cultivars, the percent pecky kernels among full grains in a panicle (hereafter referred to as percent pecky kernels) increased as the infestation rate increased (Table 2; Appendix B, Table B2). Even uninfested-caged panicles had pecky kernels (3.1%) and were 1.7% less ($P > 0.05$) than the level found in panicles infested with one RSB pair per panicle (4.8%). Uninfested-caged panicles had fewer ($P < 0.05$) pecky kernels than panicles infested with two, three, four or five RSB pairs. The differences in the percent pecky kernels in panicles infested with two to five RSB pairs per panicle were not significant ($P > 0.05$).

Differences ($P > 0.05$) were not detected in the percent pecky kernels in panicles treated with propriconazol and later infested

Table 2. Percent pecky kernels among full grains[a] in rice panicles treated with the fungicide propriconazol and later infested with different densities of rice stink bugs. Crowley, LA, 1982.

	% Pecky kernels ($\overline{X} \pm$ SE)				
Adult prs./ panicle	n	Untreated	n	1000 ppm propriconazol	$\overline{X} \pm$ SE
0[b]	26	3.8 ± 0.7 A	21	2.1 ± 0.5 B	3.1 ± 0.5 a
1	23	5.3 ± 0.9 A	21	4.3 ± 0.9 A	4.8 ± 0.7 ab
2	23	7.2 ± 1.0 A	23	6.6 ± 1.4 A	6.9 ± 0.8 bc
3	22	8.5 ± 1.6 A	23	11.3 ± 2.6 A	10.0 ± 1.5 c
4	19	7.3 ± 1.8 A	23	10.6 ± 2.5 A	9.1 ± 1.6 bc
5	24	17.4 ± 5.0 A	22	7.6 ± 1.9 A	12.7 ± 2.8 c
$\overline{X} \pm$ SE		8.3 ± 0.1 a		7.2 ± 0.1 a	

Fungicide treatment means across density treatments in a row or density means across fungicide treatments in a column followed by the same lower case letter are not significantly different at the P > 0.05 level as determined by Duncan's multiple range test. Means within a density in a row followed by the same upper case letter are not significantly different at the P > 0.05 level as determined by Duncan's multiple range test (SAS Institute 1982).

[a] Represents the percentage of spotted kernels among grains in a panicle that sank in 9% saline solution.

[b] Caged.

with RSB when compared to similar infested panicles not treated with the fungicide (Appendix B, Table B2). Only the uninfested-caged panicles treated with propriconazol had fewer ($P < 0.05$) pecky kernels than uninfested-caged panicles not treated with fungicide. Once panicles were infested, treatment with propriconazol had little effect on the level of pecky kernels.

When averaged over all infestation rates and fungicide treatments, the weights of full grains differed among the three cultivars ($P < 0.05$) (Table 3; Appendix B, Table B1). The difference between the highest ('Saturn') and the lowest weight per panicle ('Starbonnet') was 0.3 g. Labelle panicles had at least 3% more ($P < 0.05$) pecky kernels than the other two cultivars (Table 3; Appendix B, Table B2).

In 1983, the percent pecky kernels was determined for only uninfested-caged panicles and panicles infested with three pairs of RSB adults for 9 days. When combined with 1982 data from the same treatments, infested panicles had 5.0% more ($P < 0.05$) pecky kernels than uninfested-caged panicles (7.6 ± 1.0 SE, standard error, n=81 and 2.6 ± 0.3, n=78, respectively; Appendix B, Table B3). Saturn panicles had 2 to 4% fewer ($P < 0.05$) pecky kernels than Labelle or Starbonnet panicles (Table 4). Treatment with propriconazol reduced ($P < 0.05$) the percent pecky kernels only in Labelle panicles.

Panicle Age - Duration of Infestation Test. When averaged over bug days, panicles infested 20 days after flowering weighed 1.0 g more ($P < 0.05$) than panicles infested at flowering (Table 5; Appendix B, Table B4). Full grain weight of panicles infested with RSB was less ($P < 0.05$) than in uninfested panicles when averaged

Table 3. Weight of full grains[a] and percent pecky kernels among full grains in panicles of three rice cultivars. Crowley, LA, 1982 and 1983.

Rice cultivar	Full grain wt. (g)/ panicle		% Pecky kernels[b]	
	n	($\overline{X}$ ± SE)	n	($\overline{X}$ ± SE)
Saturn	173	1.8 ± 0.1 a	93	5.6 ± 0.6 a
Labelle	183	1.6 ± 0.1 b	103	9.4 ± 1.1 b
Starbonnet	186	1.5 ± 0.1 c	104	6.6 ± 1.2 a

Means in a column followed by the same letter are not significantly different at P > 0.05 level as determined by Duncan's multiple range test (SAS Institute 1982).

[a] Grains in a panicle that sank in 9% saline solution.

[b] Percentage of spotted kernels, 1982 only. Analysis of variance of percentages was done on arcsine square root transformed data.

Table 4. Percent pecky kernels among full grains[a] in panicles of three rice cultivars treated with the fungicide propriconazol. Crowley, LA, 1982 and 1983.

		% Pecky kernels ($\bar{X} \pm SE$)			
Cultivar	n	Untreated	n	1000 ppm propriconazol	$\bar{X} \pm SE$
Labelle	28	6.2 ± 1.1 A	27	4.2 ± 1.1 B	5.2 ± 0.8 a
Saturn	23	2.6 ± 0.7 A	28	3.8 ± 0.9 A	3.2 ± 0.6 b
Starbonnet	26	5.5 ± 1.1 A	28	8.4 ± 2.2 A	7.0 ± 1.3 a
$\bar{X} \pm SE$		4.8 ± 0.6 a		5.6 ± 0.9 a	

Fungicide treatment means across cultivars in a row or cultivar means across fungicide treatments in a column followed by the same lower case letter are not significantly different at the $P > 0.05$ level as determined by Duncan's multiple range test. Means, within a cultivar and by fungicide treatments, followed by the same upper case letter are not significantly different $P > 0.05$ level as determined by Duncan's multiple range test (SAS Institute 1982).

[a] Represents the percentage of spotted kernels among grains in a panicle that sank in 9% saline solution.

Table 5. Weight of full grains[a] in rice lines infested with rice stink bugs at 0, 10 and 20 days after flowering. Crowley, LA, 1982 and 1983.

	Full grain wt. (g)/ panicle ($\bar{X}$ ± SE)						
	Bug days[b]						
Panicle age (days)[c]	n	0	n	30	n	60	$\bar{X}$ ± SE
0	61	2.4 ± 0.1 A	32	1.1 ± 0.1 A	30	0.3 ± 0.1 A	1.5 ± 0.1 a
10	59	2.7 ± 0.1 A	32	1.8 ± 0.2 B	30	1.5 ± 0.1 B	2.2 ± 0.1 b
20	61	2.5 ± 0.1 A	30	2.6 ± 0.1 C	27	2.2 ± 0.1 C	2.5 ± 0.1 c
$\bar{X}$ ± SE		2.5 ± 0.1 a		1.8 ± 0.1 b		1.3 ± 0.1 c	

Infestation means across panicle age in a row or panicle age means across infestation rates in a column followed by the same lower case letter are not significantly different at $P > 0.05$ level as determined by Duncan's multiple range test. Means within a bug day in a column followed by the same upper case letter are not significantly different at $P > 0.05$ level as determined by Duncan's multiple range test (SAS Institute 1982).

[a] Weight of grains in a panicle that sank in 9% saline solution.

[b] 0, 30 and 60 bug days represent infestation rates of 0 and 3 pairs of rice stink bug adults caged for 5 days and 10 days, respectively.

[c] Panicles were considered age 0 days when anthers of top-most grain were first exserted.

across all maturity stages. As panicles matured from 0 to 20 days after flowering, infestation by RSB adults had less ($P < 0.01$) effect on the reduction in full grain weight. Caging uninfested panicles at different times after flowering had no effect ($P > 0.05$) on full grain weights.

When averaged over rice lines and panicle age at the time of infestation, the percent pecky kernels in a panicle was less ($P < 0.05$) in uninfested-caged panicles than infested panicles (Table 6; Appendix B, Table B5). Panicles infested for 60 bug days had 5.2% more pecky kernels than panicles infested for half that time. The level of pecky kernels varied ($P < 0.01$) with the bug days for each rice line. Infested Labelle and Saturn panicles, regardless of the duration of infestation, had similar ($P < 0.05$) levels of pecky kernels which were greater ($P < 0.05$) than uninfested-caged panicles. However, the percent pecky kernels in panicles of the Stuttgart (Stg) lines infested for 60 bug days was almost three times greater than for panicles infested for 30 bug days.

DISCUSSION

Panicles infested with one and two RSB adult pairs per panicle for 9 days when apical grains were in the early milk stage had 24 and 40% less full grain weight, respectively, than uninfested-caged panicles (Table 1). Full grain weights of panicles infested with four pairs of RSB adult pairs per panicle were similar to panicles infested with five pairs (Table 1). Swanson and Newsom (1962) found a 16.2 to 69.5% reduction in rough (unhulled) rice yield when panicles were infested from flowering to harvest at a rate of one RSB

Table 6. Percent pecky kernels among full grains[a] in panicles of rice lines infested with rice stink bugs. Crowley, LA, 1982 and 1983.

	% Pecky kernels ($\bar{X} \pm SE$)						
	Bug days[b]						
Line	n	0	n	30	n	60	$\bar{X} \pm SE$
Labelle	46	1.6 ± 0.3 A	24	4.6 ± 0.8 B	21	5.3 ± 1.0 B	3.3 ± 0.4 a
Saturn	48	1.7 ± 0.3 A	24	5.6 ± 1.0 B	22	7.9 ± 1.9 B	4.1 ± 0.6 a
Stg 70L1198	43	1.7 ± 0.2 A	24	4.6 ± 1.0 B	19	13.5 ± 3.8 C	5.1 ± 1.0 a
Stg 70L1217	44	1.6 ± 0.3 A	24	4.9 ± 0.7 B	21	14.1 ± 4.6 C	5.4 ± 1.2 a
$\bar{X} \pm SE$		1.6 ± 0.1 a		4.9 ± 0.4 b		10.1 ± 1.6 c	

Infestation means across lines in a row or line means across infestation rates in a column followed by the same lower case letter are not significantly different at P > 0.05 level as determined by Duncan's multiple range test. Means within a bug day in a column followed by the same upper case letter are not significantly different at P > 0.05 level as determined by Duncan's multiple range test (SAS Institute 1982). Analysis of variance was done on arcsine square root transformed data.

[a] Grains in a panicle that sank in 9% saline solution.

[b] 0, 30 and 60 bug days represent infestation rates of 0 and 3 pairs of rice stink bug adults feeding for 5 days and 3 pairs feeding for 10 days, respectively.

every four to six panicles. Panicles infested at flowering and 10 days later with three RSB adult pairs for 5 and 10 days (30 and 60 bug days, respectively) had much lower full grain weights than panicles infested 20 days after flowering (Table 5). Rolston et al. (1966) found the highest numbers of RSB in panicles in the pre-milk to soft dough stages, which includes the panicles infested at flowering and 10 days later in our study. Therefore, grains in maturity stages most preferred by RSB often result in light-weight grains as a result of feeding injury.

Saturn, a medium grain cultivar, had a higher full grain weight than the long grain cultivars, Labelle and Starbonnet (Table 3), when infested in the early milk stage with 0 to 5 RSB pairs per panicle. However, when 'Saturn' was infested with three RSB pairs for 5 and 10 days at 0, 10, and 20 days after flowering, average full grain weight was not different ($P > 0.45$) from the long grain lines, Labelle, Stg 70L1188, and Stg 70L1217. Swanson and Newsom (1962) found no association between rough rice yield and grain type (medium and long grain) in cultivars infested with RSB.

Infestation by RSB increased the percent pecky kernels at densities of two to five RSB pairs per panicle when compared to uninfested-caged panicles (Table 2). Bowling (1963) sometimes found higher ($P < 0.05$) percentages of pecky kernels in panicles infested with four RSB every 0.3 m^2 than in uninfested panicles. 'Saturn' had less pecky kernels in both years than 'Labelle' and 'Starbonnet' (Table 4). The percent pecky kernels rose with increasing bug days (Table 6). The long grain lines, Stg 70L1188 and Stg 70L1217, had higher percentages of pecky kernels than 'Labelle' or 'Saturn' when infested for 60 bug days. In contrast, Helm (1953, 1954) had noted that the short and medium grain cultivars, Magnolia and Zenith, had higher levels of pecky kernels than the long grain 'Bluebonnet' and 'Rexoro'.

Higher full grain weights were found in propriconazol-treated panicles infested with 0, 1 and 2 RSB adult pairs per panicle than similarly infested panicles not treated with fungicide (Table 10). Therefore, disease pathogens were responsible, in part, for the decrease in full grain production at low infestation rates. At higher infestation rates of three to five RSB adult pairs per panicle, weight reduction resulted from insect feeding alone or possibly in conjunction with pathogen injury if the fungicide failed to control diseases under these conditions. At high insect densities, RSB appeared to successfully compete against field fungi for rice kernels.

Uninfested panicles treated with propriconazol had significantly fewer ($P < 0.05$) pecky kernels than uninfested panicles not treated with the fungicide (Table 2). Caging panicles probably altered the micro-environment and favored the growth of grain spotting fungi. However, once panicles were infested, no differences in the percentage of pecky kernels were observed regardless of the fungicide treatment. Grain spotting fungi seem to contribute relatively little to the production of pecky kernels in infested panicles compared to that produced by RSB adults. Marchetti & Peterson (1984) also found that feeding by natural populations of RSB was the major factor in pecky kernel production. Of the grains with RSB feeding sheaths (flanges), those treated with propriconazol had 17% more discolored kernels than grains not treated with fungicide (Marchetti & Peterson 1984). Lee et al. (1984) also found higher percentages of pecky kernels in plots treated with benomyl and propriconazol than in untreated plots. When plots were treated with carbaryl alone or in conjunction with fungicides, significantly fewer pecky kernels were found than in untreated plots.

Feeding by RSB on rice grains produces light-weight grains and pecky kernels. The reduction in rough rice yields causes greater economic loss than pecky kernel production (Douglas & Tullis 1950, Fryar et al. 1986). The relative amounts of these two types of injury depend on the maturity stage of the panicle at the time of feeding and the infestation level. RSB were more important in causing discolored kernels than grain spotting fungi. Reduction in full grain weights at infestation rates of three to five RSB adult pairs per panicle appeared to be caused almost entirely by RSB feeding damage. However, at lower infestation rates pathogens contributed to yield reduction. The differential responses of rice lines to RSB injury indicates the presence of resistance which can be used as a part of a RSB management strategy.

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CHAPTER IV

A SCREENING METHOD FOR DETECTING RESISTANCE IN RICE TO THE RICE STINK BUG (HEMIPTERA: PENTATOMIDAE)

This chapter is written in the style of the Journal of Economic Entomology

ABSTRACT

Flotation in a 9% saline solution provided an accurate and rapid method for separating undamaged rice grains from those damaged by the rice stink bug (RSB), Oebalus pugnax (F.). The linear correlation coefficient between the percent damaged kernels (hulled grains) and sinking grains (not hulled) was at least -0.95 in all tests. The percentage of misclassified grains, which consisted of floating grains with undamaged kernels and sinking (full) grains with damaged kernels, did not exceed 13.8%.

Infestation with three RSB per panicle reduced the percentage of sinking grains by about 37% compared to uninfested-caged panicles. The percent full grains from panicles treated with a single fungicide application of 1000 ppm propriconazol and later infested with RSB was not significantly different from similarly infested panicles not treated with fungicide.

Infestation of panicles at flowering resulted in the greatest reduction in the percent full grains when compared to panicles infested either 10 or 20 days after flowering. Panicles infested with three pairs of RSB per panicle for 10 days had 12% fewer full grains than panicles infested for 5 days and 37% fewer full grains than uninfested-caged panicles. 'Labelle' had a higher percentage of full grains than 'Saturn', Stg 70L1188 or Stg 70L1217.

Panicles of 'Starbonnet' infested with four or six RSB females per panicle had the greatest reduction in the percentage of full grains when compared to males or pairs. Males and pairs reduced the percentage of full grains in a panicle by a similar amount.

INTRODUCTION

The rice stink bug, *Oebalus pugnax* (F.), is an economic pest of rice, *Oryza sativa*, in the southern United States. Populations increase on wild grass hosts, such as vasey grass, *Paspalum urvillei* Steudel (Douglas 1939) and barnyard grasses, *Echinochloa* spp., and move to rice fields when panicles emerge (Odglen & Warren 1962). The rice stink bug (RSB) feeds on developing grains of the rice panicle by inserting its stylets into the grain and withdrawing part of the endosperm. The degree of damage to the kernel (hulled grain) depends on maturity of the grain when injury occurs. Grains fed upon in the early milk to dough stages have light-weight kernels almost devoid of endosperm. Kernels of grains damaged in the dough stage result are structurally weakened, break more easily during milling and are often darkly spotted ("pecky"). Feeding punctures can provide additional entry sites for grain spotting fungi such as *Bipolaris* spp. and *Curvularia* spp. (Douglas & Tullis 1950).

No rice cultivars with high levels of resistance to RSB have been found. Nilakhe (1976) evaluated 228 cultivars from the 1973 Arkansas disease nursery for tolerance to RSB feeding injury and found only 26 cultivars with small weight per kernel differences between the uninfested and infested panicles. The percentage of pecky kernels for these rice cultivars, determined by the method described by Swanson and Newsom (1962), was very high (71-100%). Robinson et al. (1980) confined various numbers of RSB pairs on rice panicles for seven to eight days and found that panicles infested with three pairs per panicle had a significantly lower percentage of full grains than uninfested panicles. Unfortunately, these methods are either time consuming or unreliable.

The objective of the research reported here was to develop an effective screening method that could be used to evaluate rice cultivars for their resistance to RSB. The parameters studied were RSB density, sex, fungicide treatment, panicle age at the time of infestation and the duration of the infestation period.

METHODS AND MATERIALS

Rice Stink Bug Density and Fungicide Test.

Rice cultivation. The rice cultivars, Labelle, Saturn and Starbonnet, were planted on 24 May 1982 and 31 May 1983 to ensure that panicle emergence would coincide with peak field populations of RSB (authors' unpublished data). Seeds of each cultivar were planted using a drop cone planter in a randomized complete block design (1982, four blocks; 1983, three blocks) in 2-m rows spaced 0.5 m apart. The herbicides, propanil (4 EC) and thiobencarb (8 EC) were applied at a rate of 3.3 kg per ha approximately 3 weeks after planting. Granular fertilizer was applied once each year at a rate of 112 kg N, 56 kg P_2O_5, and 56 kg K_2O per ha prior to permanent flood. Fields were flooded 23 June 1982 and 7 July 1983 to establish a flood that was maintained until harvest. Carbofuran was applied postflood at a rate of 0.5 kg per ha for rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, control.

Fungicide application. To control grain spotting fungi, random panicles within a row were sprayed until run-off with a 1000 ppm solution of propriconazol (Tilt 3.6 EC) using a 0.5-liter hand-held air pump sprayer. Panicles were sprayed after the completion of flowering to minimize interference with fertilization. Propriconazol appears to have little effect on RSB mortality. There were no significant differences ($P < 0.05$) in the mortality of RSB 120 hours after infestation of 'Saturn' panicles treated with 0, 1000, 2500, 5000, 7500 and 10,000 ppm propriconazol (Chapter I). Average mortality was low and ranged from 0.0 to 8.3% across all fungicide concentrations, though RSB were caged two hours after application at a high density of five pairs per panicle.

Field infestation and harvest. Copulating pairs of RSB were hand-collected from headed grasses and placed in polyethylene bags. The insects were chilled (4 °C for ca. 2 min), sorted by sex into groups of 20 to 60 insects and placed into polyethylene bags containing vasey grass or rice panicles and water-moistened paper towels. The bugs were held at room temperature (ca. 24 °C) and used for infestations within 2 days of collection. Nylon tulle cages (30.5 cm long, 7.5 cm wide and 64 openings/ cm^2) were used for confining the insects on the rice panicles. One corner was left unsewn and was pinched closed with a 3.8 cm length of twist-tie.

Panicles were infested when the apical kernels were in the early milk stage. RSB (0, 1, 2, 3, 4, or 5 pairs) were placed in a cage and confined with a twist-tie to the top of the cage. A thin flexible tube, (30.5 cm long by 2.5 cm diameter) slit once lengthwise, was used to facilitate caging and minimize injury to panicles. The panicle was enclosed in the tube by slipping the panicle through the enlarged slit. A cage with confined RSB was slipped over the tube and panicle, the tube was pushed down the stem and removed, and then the cage was closed below the neck node with nylon twine. The twist-tie was removed to allow RSB access to the panicle.

RSB were allowed to feed for 9 days. Infested panicles were checked every other day for insect mortality and dead insects were replaced with live ones of the appropriate gender through the unsewn cage corner. Infestations were terminated by decapitating test insects. Cages were left on panicles to discourage feeding by RSB naturally present in the plots. At maturity, the panicles were harvested (25 Sept. 1982 and 6 Oct. 1983), the cages removed and panicles were stored in paper envelopes at -4 °C.

Evaluations. Frozen panicles were thawed at room temperature (ca. 21 °C) for 2 days and then dried at 42 °C for an additional 2 days in a drying oven (Precision Scientific Model 8). Individual panicles were hand threshed and were allowed to equilibrate at room temperature (ca. 22 °C) for at least 2 weeks before processing.

The threshed grains in a panicle were mixed with a 9% saline solution (reagent grade NaCl and distilled water) in a 250-ml beaker. Floating grains were removed with a perforated plastic spoon. Both sets of grains were rinsed under tap water and placed between two layers of filter paper in separate 90-mm glass petri-dish bottoms, dried in a microwave oven (Panasonic Model NE-8030) for 45 seconds at medium heat and then counted.

All grains were hand-hulled. The total number of damaged kernels in a panicle consisted of all damaged grains that floated and sank. Damaged kernels included pecky, fully elongated but shrunken, partly elongated and aborted kernels. Any undamaged kernels of grains that floated or damaged kernels of grains that sank were considered misclassified. Sinking grains, damaged kernels and misclassifed grains were each calculated as a percentage of the total number of grains in the panicle to eliminate differences in panicle sizes among and between rice cultivars. Damaged grains that sank in almost all cases, were pecky. In 1982, panicles infested at all RSB densities tested were evaluated for damage. Because this step was so time consuming, only the uninfested-caged and those exposed to three pairs of RSB per panicle were evaluated in 1983.

Analyses. Linear correlations were run between percent damaged kernels and sinking grains using CORR (SAS Institute 1982a). All percentages were transformed using the arcsine square root transformation for analyses. Data in 1982 were analyzed using the General Linear Models (GLM) procedure (SAS Institute 1982b) as a randomized complete block design with three factors: seven levels of RSB density, two levels of fungicide treatment and three rice cultivars. Significant main effects were separated using Duncan's multiple range test (a GLM option) and significant interactions were examined using contrasts.

The results of 1983 were combined with those of 1982 for the same treatments and analyzed over years as a factorial with two levels of RSB density, two levels of fungicide treatment and three rice cultivars. Significant main effects and interactions were examined as above.

Panicle Age and Duration of Infestation Test.

Rice cultivation. The rice cultivars, Labelle and Saturn and two breeding lines, Stg 70L1217 and Stg 70L1188, were planted on 8 June 1982 and 31 May 1983. Seeds of each cultivar and line (hereafter referred to collectively as lines) were planted in a randomized complete block design (1982, five blocks and 1983, three blocks), fertilized, treated for weeds and rice water weevil larvae as in the above test. A permanent flood of 10 to 15 cm was maintained until harvest beginning 2 July 1982 and 7 July 1983.

Field infestation and harvest. Panicles were tagged to record date of flowering when anthers of the apical grains were visible (Day 0). On days 0, 10 and 20, panicles were caged with 0 or 3 pairs of RSB per panicle in the manner described above. RSB were allowed to feed for 5 or 10 days on panicles of each age. Mortality was checked and the study was terminated as described above.

Evaluations. Panicles were processed using the method previously described. All treatments of both years were evaluated.

Analyses. Correlations, analysis of variance and separations of means were performed as in the previous experiment. To simplify computer analyses, the infestation rate was multiplied by the duration of infestation to obtain 0, 30 and 60 "bug days". The results were averaged over two years and were analyzed as a randomized complete block design with the factorial treatments: three levels of bug days, three levels of panicle age, and four rice lines.

RSB Sex And Density Test.

A single row of 'Starbonnet' was planted at random in each block with the other lines in the panicle age and duration of infestation test and along each levee as a border row. When apical grains were in the early milk stage on 16 September 1982, panicles were infested with either males, females, or pairs at densities of 0, 2, 4 or 6 RSB per panicle. Each treatment combination appeared once within a particular block and in one of the two border rows, so each treatment combination was replicated 10 times. RSB were allowed to feed for 9 days and dead insects were replaced every other day with live insects of the appropriate gender. Panicles were harvested when mature, 19 October 1982, and treated as described in the above tests except that only the numbers of grains that floated or sank were collected.

The data were transformed as described above. They were analyzed as a randomized complete block design with two factors, RSB density and sex using GLM (SAS Institute 1982b). Separations of means and interactions were investigated as previously described.

RESULTS

Rice Stink Bug Density-Fungicide Treatment Test.

The significant negative linear correlation coefficient, $r = -0.99$ ($n=305$) between the percent damaged kernels and the percent sinking grains in 1982 indicated that grains that sink in 9% saline solution can be used to estimate the amount of damage resulting from feeding by pairs of RSB ($P < 0.01$). The correlation coefficient was the same ($r = -0.99$) within each fungicide treatment group. Because of the high but negative correlation between the percent damaged kernels and sinking grains and to eliminate redundancy, only sinking grains (hereafter referred to as full grains) will be discussed.

Uninfested-caged panicles had 9.7% ($P < 0.05$) fewer full grains than uninfested-uncaged panicles (Table 1; Appendix C, Table C2). Caged panicles were observed to remain wet longer with morning dew than uncaged panicles and the altered micro-environment probably favored disease development. The percent full grains declined ($P < 0.05$) with

Table 1. Percent full grains[a] in rice panicles infested with rice stink bugs. Crowley, LA, 1982.

No. of adult prs./ panicle	n	% Full grains/ panicle ($\bar{X} \pm$ SE)
0 Uncaged	30	78.9 ± 1.5 a
0 Caged	47	69.2 ± 2.5 b
1	45	52.3 ± 2.9 c
2	46	38.5 ± 1.8 d
3	46	24.3 ± 2.2 e
4	45	15.2 ± 2.0 f
5	46	13.7 ± 1.7 f

Means in a column followed by the same letter are not significantly different at P > 0.05 level as determined by Duncan's multiple range test (SAS Institute 1982). Analysis of variance was done on arcsine square root transformed data.

[a] Grains that sank in 9% saline solution.

increasing RSB density from zero to four RSB pairs per panicle. Infestation with four RSB pairs per panicle resulted in a similar percentage of full grains as five RSB pairs per panicle (15.2 and 13.7, respectively).

The percent misclassified grains in uninfested-uncaged panicles was 1.6% less ($P < 0.05$) than the level found in uninfested-caged panicles (3.6 ± 0.4 SE, standard error, n=30 and 5.2 ± 0.5, n=47, respectively). In general, the percent misclassified grains declined ($P < 0.05$) as the RSB density per panicle increased and ranged from 5.2 for uninfested-caged panicles to 1.7 (± 0.2, n= 46) for panicles infested with five RSB pairs per panicle (Appendix C, Table C3).

Panicles treated with 1000 ppm propriconazol had 6.8% more ($P < 0.05$) full grains than panicles without any fungicide treatment (43.3% ± 2.2, n= 152 and 36.5% ± 2.2, n=153, respectively; Appendix C, Table C2). However, treatment with propriconazol did not significantly ($P > 0.30$) decrease the percent misclassified grains (Appendix C, Table C3).

Averaged over all RSB densities and fungicide treatments, 'Starbonnet' panicles had the lowest ($P < 0.05$) percent full grains (31.9 ± 2.5, n=107) compared to 'Saturn' (42.7 ± 2.8, n=94) and 'Labelle' (45.7 ± 2.7, n=107) panicles. The percent misclassified grains ranged from 2.5 (± 0.2, n=107) in 'Starbonnet' to 4.2 (± 0.5, n=94) in 'Saturn'.

In the 1982 studies, the percent full grains decreased at a near constant rate from one to three pairs of RSB per panicle and thereafter declined much more slowly (Table 1). An infestation rate of three pairs of RSB per panicle decreased the amount of full grains by almost 45%

when compared to uninfested-caged panicles. Data from the same treatments in 1982 and 1983 were combined to obtain a two-year average. The negative linear correlation coefficient, $r = -0.98$ ($n=160$) between the percent full grains and the percent damaged kernels was significant ($P < 0.01$) and was the same within each fungicide treatment ($r = -0.98$; $n=82$ and 78 for 0 and 1000 ppm, respectively).

The percent full grains in panicles was 8.0% higher ($P < 0.01$) in 1983 than in 1982 (55.0 ± 2.6, n=67 and 47.0 ± 2.5, n=93; Appendix C, Table C5). Severe storms during two days of infestation in 1983 decreased the amount of feeding by RSB. Averaged over both years, the percent full grains of each infestation level varied ($P < 0.01$) with the fungicide treatment. Among uninfested panicles, those treated with propriconazol had 12.5% more full grains than panicles not treated with the fungicide (Table 2). However, among panicles infested with three pairs of RSB, there was only a 3.6% difference in the percent full grains between propriconazol-treated and untreated panicles (Table 2). Therefore, the propriconazol treatment increased the percent full grains in uninfested panicles, but once infested, the percent full grains was not affected by the fungicide treatment. Misclassified grains ranged from 4.2% (± 0.4, n=41) for infested panicles not treated with propriconazol to 6.9% (± 0.7, n=41) for uninfested-caged panicles not treated with fungicide (Appendix C, Table C6).

All three cultivars differed ($P < 0.05$) from one another in the percentage of full grains (Appendix C, Table C5). The percent full grains in 'Labelle' panicles (61.2 ± 3.3, n=55) was 15 and 24% higher

Table 2. Percent full grains[a] in rice panicles treated with the fungicide propriconazol and later infested with rice stink bugs. Crowley, LA, 1982 and 1983.

	% Full grains/ panicle ($\bar{X}$ ± SE)			
Propriconazol	No. of adult prs./ panicle			
(ppm)	n	0	n	3
0	41	63.3 ± 3.2	41	34.2 ± 2.8
1000	37	75.8 ± 1.8	41	30.6 ± 2.6

$P < 0.01$ for the propriconazol by infestation level interaction.

[a] Grains that sank in 9% saline solution.

than that found in 'Saturn' and 'Starbonnet' (47.9 ± 3.3, n=50 and 41.7 ± 3.3, n=55, respectively). The lack of a significant ($P > 0.60$) cultivar by infestation level interaction indicates that differences in the percent full grains were small between uninfested and infested panicles for all cultivars tested. The percent misclassified grains ranged from 4.0 ± 0.4, n=55) in 'Labelle' to 6.8 (± 0.9, n=50) in 'Saturn' (Appendix C, Table C6).

Panicle Age-Duration of Infestation Test.

As in the other tests, the percent damaged kernels was highly correlated with the percent full grains (r= -0.97, n=398, $P < 0.01$). This linear correlation increased as "bug days" increased (0 bug days = uninfested: r= -0.89, n=198; 30 bug days: r= -0.98, n=103; 60 bug days: r= -0.98, n=97; $P < 0.01$). As panicle age at the time of infestation increased, the correlation between the two variables declined (0 days = flowering: r= -0.99, n=134; 10 days after flowering: r= -0.95, n=134; 20 days after flowering: r= -0.87, n=130; $P < 0.01$). Since these correlations are very high, discussion will be limited to to the percent full grains.

The interaction between infestation rate, line, and panicle age at the time of infestation for the percent full grains in a panicle was significant ($P < 0.01$; Appendix C, Table C8). A major factor contributing to this interaction was the small reduction in the percent full grains (16.3%) in 'Saturn' panicles infested at flowering for 30 bug days compared to uninfested 'Saturn' panicles caged at flowering. The reduction in the percent full grains in similarly treated panicles of the remaining lines ranged from 41.3 to 51.2%.

Percent full grains varied ($P < 0.01$) with bug days for each panicle age at the time of infestation (Table 3; Appendix C, Table C8). The difference in the percent full grains between uninfested and panicles infested for 30 bug days was greater ($P < 0.01$) at flowering (38.5%) than 10 days after flowering (25.3%). For similarly treated panicles 20 days after flowering, the 7.4% reduction in the number of full grains was significantly less ($P < 0.01$) than panicles infested 10 days after flowering. When the infestation level doubled, the decline in the percent full grains for panicles infested at flowering was almost three times that observed in panicles infested 10 days after flowering ($P < 0.01$). However, the decline in the percent full grains from panicles infested for 30 and 60 bug days, 10 and 20 days after flowering, was similar ($P > 0.10$).

The percent misclassified grains also varied ($P < 0.01$) with bug day for each panicle age at the time of infestation (Appendix C, Table C9). Panicles infested at flowering for 60 bug days had only 1.4% (± 0.4, n=30) misclassified grains whereas panicles infested 20 days after flowering for 60 bug days had the highest misclassified grains, 8.9% (± 1.2, n=27).

When averaged over bug days and panicle age at the time of infestation, the percent full grains per panicle differed ($P < 0.01$) among rice lines (Appendix C, Table C8). 'Labelle' had 68.1% (±2.6, n=92) full grains and was higher ($P < 0.05$) than that found in 'Saturn'(54.2% ± 2.0, n=96), Stg 70L1217 (57.2% ± 2.7, n=86) or Stg 70L1188 (59.2% ± 2.6, n=89). The percent misclassified grains ranged from 3.5 (± 0.3, n=92) in 'Labelle' to 7.9 (± 0.6, n=96) in 'Saturn' panicles. The highest percentage of misclassified grains

Table 3. Percent full grains[a] in rice panicles infested with rice stink bug adults at different times after flowering. Crowley, LA, 1982 and 1983.

	% Full grains/ panicle ($\bar{X}$ ± SE)						
	Bug days[b]						
Panicle age (days after flowering)	n	0	n	30	n	60	$\bar{X}$ ± SE
0	61	72.8 ± 1.6	32	34.3 ± 2.1	30	9.9 ± 2.3	47.4 ± 2.6 a
10	59	75.1 ± 2.0	32	49.8 ± 2.3	31	42.4 ± 2.2	60.1 ± 1.8 b
20	61	76.7 ± 1.3	30	69.3 ± 1.8	27	64.2 ± 2.5	72.0 ± 1.1 c
$\bar{X}$ ± SE		74.8 ± 1.0 a		50.7 ± 1.9 b		38.0 ± 2.7 c	

Means in a column or row followed by the same letter are not significantly at P > 0.05 level as determined by Duncan's multiple range test (SAS Institute 1982).

[a] Grains that sank in 9% saline solution.

[b] 0, 30 and 60 bug days represent infestation rates of 0 and 3 pairs of rice stink bugs feeding for 5 and 10 days, respectively.
respectively.

occurred in Stg 70L1188 panicles infested 20 days after flowering for 60 bug days (13.8 ± 4.7, n=5; Appendix C, Table C9).

Rice Stink Bug Sex and Density Study.

Percent full grains in 'Starbonnet' panicles was affected by the sex of RSB within a density level ($P < 0.01$; Table 4; Appendix C, Table C10). Males and pairs of RSB produced a similar reduction ($P < 0.01$) in the percent full grains as RSB density increased. The percent full grains in panicles infested with two females per panicle (46.6 ± 2.9) was similar to those infested with one pair (46.7 ± 2.8) and 5% more than that found in panicles infested with two males (41.7 ± 3.4). At densities of four RSB per panicle, the reduction in full grains was at least 8% greater for panicles infested with females than for panicles infested with males or pairs. At the highest infestation rate, full grains declined by almost 15% for panicles infested with females compared to panicles infested with six males or three pairs of RSB per panicle.

DISCUSSION

Floating rice grains were easily damaged and likely to be lost during hand-threshing and processing. Therefore, sinking grains were used to determine the accuracy of the 9% saline solution for separating damaged grains from undamaged grains. The flotation technique is effective for separating damaged from undamaged grains and would save from one to two person-hours needed to hull a panicle and separate damaged from undamaged kernels. The 9% saline solution used in the present study has a specific gravity of 1.06 which falls

Table 4. Percent full grains[a] in 'Starbonnet' rice infested with different densities and sexes of rice stink bugs. Crowley, LA, 1982 and 1983.

	% Full grains/ panicle ($\bar{X}$ ± SE)						
	No. of rice stink bugs[b]/ panicle						
Sex	n	2	n	4	n	6	$\bar{X}$ ± SE
Females	9	46.9 ± 2.9	10	33.2 ± 2.3	10	12.6 ± 2.2	30.2 ± 3.0 a
Males	8	41.7 ± 3.4	9	40.3 ± 2.6	10	27.3 ± 2.4	35.9 ± 2.0 b
Pairs	10	46.7 ± 2.8	10	41.8 ± 2.6	10	27.0 ± 2.4	38.5 ± 2.1 b
$\bar{X}$ ± SE		45.2 ± 1.7 a		38.4 ± 1.6 b		22.3 ± 1.8 c	

Means in a row or column and followed by the same letter are not significantly different at $P > 0.05$ level as determined by Duncan's multiple range test (SAS Institute 1982).

[a] Grains that sank in 9% saline solution.

[b] % Full grains for uninfested-caged panicles = 60.2 ± 1.6, n=10.

in the range (1.05-1.12) recommended by Matsushima (1970) to use in separating ripened from imperfectly ripened grains of rice.

The highest average percent misclassified grains was 13.8 and occurred in Stg 70L1188 panicles infested 20 days after flowering for 60 bug days. Using a solution with a specific gravity of 1.06 and 37 Japanese varieties, Matsushima (1970) found that 0 to 2% of the fully ripened grains floated and that 4 to 10% of the imperfectly ripened grains sank. Generally, the percent misclassified grains was higher for uninfested panicles and for panicles infested much later in maturity. A single application of propriconazol did not greatly affect the percentage of misclassified grains. Most of the error in classification probably occurred because of the presence of "undamaged" grains that floated in the saline solution. Many of the "undamaged" kernels were either unspotted and chalky (not due to insect damage) or small immature grains located at the base of panicles.

When 'Labelle', 'Saturn' and 'Starbonnet' were infested for 9 days starting when the apical grains were in the milk stage, the percent full grains in panicles decreased at a similar rate as RSB density increased. However, 'Labelle' and 'Saturn' averaged more ($P < 0.05$) full grains than 'Starbonnet' in 1982 and 1983. The decrease in percent full grains between uninfested and 'Saturn' panicles infested for 30 bug days at flowering was less than half that observed in 'Labelle', Stg 70L1188 and Stg 70L1217. Flowering 'Saturn' panicles appeared to be more tolerant to RSB infestations of short duration (5 days). When averaged over all infestation rates and panicle ages at the time of infestation, 'Labelle' had at least 9%

more full grains than the other three lines.

For varietal screening purposes, infestation of panicles when the apical grains are in the milk stage or 10 days after flowering is recommended. At flowering, panicles are very sensitive to mechanical injury, and even movement by RSB could disrupt fertilization, resulting in sterile grains. Conversely, infestation 20 days after flowering especially at lower infestation rates may not detect differences in tolerance or antixenosis as lines would be near physiological maturity and would be less susceptible to RSB injury.

Caging uninfested panicles reduced the percent full grains by almost 10% compared to uninfested-uncaged panicles (Table 1). Uninfested-caged panicles treated with a single application of propriconazol had 12.2% more ($P < 0.05$) full grains than similar panicles not treated with the fungicide (75.9 ± 2.1, n=21 and 63.7 ± 3.9, n=26, respectively). Propriconazol had little ($P > 0.20$) effect on the percent full grains in uninfested-uncaged plants. Simply caging panicles decreased the percent full grains by favoring fungal disease development. To serve as an appropriate check in varietal screening, panicles should be treated with fungicide and caged since lines may respond differently to caging and/or fungi.

An infestation rate of two RSB per panicle resulted in a 30% reduction in full grains compared to uninfested-caged panicles (Table 1). Infestation with three pairs per panicle should detect differences in resistance without requiring the replacement of dead insects. Differences in response of rice lines to RSB injury were observed at an infestation rate of three pairs for 5 days (30 bug days) when compared to uninfested-caged panicles. Infesting panicles with three pairs for 5 rather than 10 days would reduce variability in RSB density due to mortality.

The sex of RSB used for screening germplasm must be consistent. When panicles were infested with two RSB each, differences in the percent full grains were small. However at densities of four and six RSB per panicle, females caused a greater reduction in the percent full grains than males or pairs. These findings are consistent with Bowling's (1979) laboratory observations that female RSB produced twice the number of feeding punctures compared to males on 'Labelle' panicles during a 72-hour period.

Once panicles are caged, disruption of panicle development by rice stalk borers, *Chilo plejadellus* Zincken, is difficult to detect. The extent of injury to panicles depends on when movement of translocates ceased, but damage is often seen as empty grains. Because this injury is similar to RSB injury when infestation occurs at flowering or when the apical grains are in the milk stage, rice stalk borers must be controlled.

From this study, we conclude that for medium and long grain rice lines, damaged grains can be separated, with an acceptable level of error, from undamaged ones by flotation in 9% saline solution. Lines differ in their resistance to RSB depending on the physiological stage of panicle development when injury occurs and the rate of RSB infestation during a fixed period of time. An effective screening method would be to compare within a line the difference in the percent full grains between uninfested-caged panicles and panicles infested with three pairs of RSB for 5 days. Panicles should be infested 10 days after flowering or when apical grains are in the milk stage. Grain spotting fungi and *C. plejadellus* that can produce similar type injuries as RSB should be controlled.

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CHAPTER V

EVALUATION OF RICE LINES FOR RESISTANCE TO RICE STINK BUGS

This chapter is written in the style of the
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ABSTRACT

Rice panicles were infested when apical grains were in the early milk stage with three rice stink bug (RSB), Oebalus pugnax (F.), adult pairs for 9 days. Undamaged grains were reduced from 38.3 to 63.7% and 11.4 to 20.5% of the grains were pecky among the rice lines Stg 70M11309, Stg 70M7046, Saturn, Stg 69M5164 and Stg 70M3901. These lines have been shown previously to possess tolerance to feeding injury by RSB. Seventeen of the 57 lines screened in 1983 had less than a 26% reduction in numbers and/or weights of full grains after RSB infestation. These resistant lines included Lebonnet, Skybonnet, Bellemont, Newrex, Belle Patna and CI 9881.

INTRODUCTION

Adults and nymphs of the rice stink bug (RSB), Oebalus pugnax (F.), feed on headed rice throughout the southeastern United States. Grains damaged early in development often abort or become light-weight and are lost during harvest. Grains damaged in the later dough stages are often pecky, structurally weakened and break more easily during milling than those undamaged. Pecky kernels resulting from RSB feeding have large circular lesions that are chalky, with a small dark puncture near the center (Douglas & Tullis 1950, Lee & Tugwell 1980).

RSB populations are partly controlled by natural enemies (Odglen & Warren 1962, Gifford et al. 1973a, 1973b), and effective insecticides are available to suppress insect populations when they reach the action threshold (Anon. 1986). Resistant rice lines to some pests of rice have been used as part of pest management strategies. Bowling (1979) found the rice line, RU 7603069 ('Bellemont') to be nonpreferred based on the low number of feeding sheaths on grains. This line also appeared to be tolerant because of small weight differences between injured and normal grains. Nilakhe (1976) found similar levels of tolerance in Stg 70M7046, Stg 71M11309, Stg 69M5164, Stg 70M3901, Saturn, Labelle and Starbonnet rice based on low differences in grain weights of uninfested as compared to panicles infested with RSB. No differences were found in the percent damaged kernels of uninfested-caged and panicles infested with three pairs of RSB in the rice lines RU 7603015 (Skybonnet), RU 7403025, RU 7802192, RU 8103062, Labelle, Starbonnet, Lemont and Newrex (Robinson et al. 1981). Because these evaluation results were preliminary, additional lines were evaluated for resistance to RSB adults.

METHODS AND MATERIALS

1981 Evaluation. Six rice varieties in maturity group II (86-95 DH), Calrose, Carolina Gold, Century Patna 231, Early Wataribune, M101 and Saturn, and two breeding lines, Stg 70M7046 and Stg 71M11309 were planted on 15 April 1981 in a randomized block design. A second planting on 21 May 1981, included the same rice cultivars plus two additional breeding lines, Stg 69M5164 and Stg 70M3901. Because of the small amount of seed available for the breeding lines, each was planted in only two of the five blocks. Six grams of seed of each cultivar and breeding line (hereafter referred to as lines) were planted in 2-m rows spaced 0.5 m apart using a drop cone planter. The herbicides, propanil (4 EC) and thiobencarb (8 EC) were applied at a rate of 3.3 kg AI/ ha 3 to 4 weeks after planting.

A single application of granular fertilizer was made to each planting at a rate of 112 kg N, 56 kg P_2O_5 and 56 kg K_2O/ ha, 20 May and 18 June, respectively, after which a permanent flood of 10 to 15 cm was maintained until harvest, 28 August and 25 September, respectively. Carbofuran (3G) was applied at a rate of 0.5 kg AI/ ha for rice water weevil, Lissorhoptrus oryzophilus Kuschel, control 27 May and 26 June, respectively.

When the apical grains in panicles of a rice line were in the early milk stage, three panicles of each line in a block were infested with three pairs of RSB adults per panicle and three panicles were caged without any bugs. RSB used for infestations were collected from headed grasses along rice levees and placed in polyester organdy cages (30 cm long X 7.5 cm wide). The cage with the insects was then placed over the panicle and secured at the neck node with a thin strip of organdy. Mortality was checked every other day and dead bugs were replaced with live ones of the appropriate sex through the small opening at the corner of the cage. At the end of 9 days, the RSB were decapitated, but the cages remained on the panicles to discourage feeding by field populations of RSB.

Panicles were harvested at maturity and stored in paper bags at -4 °C until evaluation. Panicles were threshed and grains were hulled by hand. Each kernel (hulled grain) was placed in one of two categories, damaged or undamaged. Damaged kernels were divided into two groups, pecky and light-weight. Light-weight kernels included fully elongated but shrunken, partly elongated, and aborted kernels. Undamaged, pecky and light-weight kernels in infested and uninfested panicles were expressed as a percentage of the total number of kernels in a panicle. Means and standard errors (SE) were calculated using MEANS (SAS Institute 1982). The average percent pecky and light-weight kernels in infested panicles of a line were adjusted for the level of damage observed in uninfested panicles of the same line. The percent reduction in undamaged kernels per panicle was calculated as the difference in percent undamaged kernels in infested and uninfested panicles of a line divided by the percent undamaged kernels in uninfested panicles of the same line.

1982 and 1983 Evaluations. Rice lines, predominantly from the foliar disease nursery, were infested in 1982 and 1983 with field-collected RSB adult pairs when apical grains were in the early milk stage. A nylon tulle cage (30.5 cm long and 7.5 cm wide, 64 openings/ cm^2) with three females and three males was placed over the panicle and secured with nylon twine at the neck node. Control panicles were caged in a similar manner, but without bugs. Two uninfested and two infested panicles were evaluated for each line. The duration of the infestation period, mortality check, replacement of RSB, and termination of infestation were the same as in the 1981 screen.

Panicles were harvested at maturity, placed in paper envelopes, and stored at -4 °C until evaluation. At evaluation, frozen panicles were thawed at room temperature (ca. 21 °C) for 2 days and then dried at 42 °C for an additional 2 days in a drying oven (Precision Scientific Model 8). Individual panicles were hand-threshed and allowed to equilibrate at room temperature (ca. 22 °C) for at least 2 weeks before processing.

Damaged grains in a panicle were separated from undamaged ones using a 9% saline solution. Floating (predominantly damaged) and sinking grains (predominantly undamaged) were rinsed under tap water and blotted dry on paper towels for ca. 1 min. Each group was placed between two layers of filter paper in separate 90-mm glass petri-dish bottoms, heated in a microwave oven (Panasonic Model NE-8030) for 45 sec at medium heat, cooled for at least 5 min at room temperature and then weighed and counted.

The number and weights of sinking grains (hereafter referred to as full grains) were calculated as a percentage of the total number of grains in a panicle. Means and standard errors were obtained using MEANS (SAS Institute 1982). The percent reduction in the number and weights of full grains per panicle caused by RSB adults was calculated in a similar way to the percent reduction in undamaged kernels per panicle in the 1981 evaluation.

RESULTS

1981 Evaluation. Higher percentages of light-weight kernels (28.7- 93.2) (Table 1) relative to pecky kernels (4.3 - 21.6) (Table 2) were observed in infested panicles. Uninfested panicles also had light-weight (7.6 - 26.2%) (Table 1) and pecky kernels (1.0 - 7.3%) (Table 2). These results are in agreement with Yoshida (1981) who had found that normally about 15% of rice spikelets will not be filled.

Stg 71M11309 had the smallest adjusted percentage of light-weight kernels (15.2) (Table 1). Relative to the other lines, Saturn had a low adjusted percentage of light-weight kernels, but was more than

Table 1. Percent light-weight kernels[a] in selected rice lines infested with three pairs of field-collected rice stink bug adults for 9 days. Crowley, LA, 1981.

	% Light-weight kernels/ panicle ($\overline{X}$ ± SE)				
Rice line	n	Uninfested	n	Infested	Adjusted infested[b]
Stg 71M11309	4	15.9 ± 3.4	4	28.7 ± 6.6	15.2
Saturn	22	21.1 ± 2.8	21	49.4 ± 4.2	35.9
Stg 70M7046	3	10.5 ± 2.4	4	47.4 ± 11.2	41.2
Stg 70M3901	6	12.8 ± 3.5	5	53.8 ± 6.3	47.0
Stg 69M5164	6	14.9 ± 4.1	6	59.2 ± 9.2	52.1
Carolina Gold	18	11.8 ± 2.0	24	57.7 ± 4.5	65.4
Early Wataribune	16	25.7 ± 4.1	22	74.6 ± 3.0	65.8
Calrose	17	7.6 ± 1.2	24	70.4 ± 3.7	68.0
Century Patna 231	23	18.6 ± 2.7	25	80.9 ± 3.7	76.5
M101	22	26.2 ± 2.6	23	93.2 ± 1.0	90.8

[a] Empty, partially elongated and fully elongated-shrunken.

[b] Infested adj. for uninfested = $\frac{\overline{X}\text{ Uninfested} - \overline{X}\text{ Infested}}{100 - \overline{X}\text{ Uninfested}} \times 100.$

twice the level observed in Stg 71M11309. All but 10% of the M101 kernels were light-weight. Generally, lines with high adjusted percentages of light-weight kernels had low adjusted percentages of pecky kernels. 'Saturn' and Stg 71M11309 had the highest adjusted percentage of pecky kernels, 20.5 and 19.2, respectively, while 'Early Wataribune' and 'M101' had only 2.9 and 3.1%, respectively (Table 2).

Infestation by RSB adults reduced the number of undamaged kernels per panicle from 38.3 to 96.6% relative to uninfested panicles (Table 3). The smallest reduction was observed in Stg 71M11309 panicles while the largest reduction occurred in 'M101' panicles. Infested panicles of Stg 70M7046 and 'Saturn' had more than a 60% reduction in undamaged kernels, which was 1.6 times greater than the reduction observed in Stg 71M11309.

1982 and 1983 Evaluations. In both years, the percent reduction in the number of full grains in infested panicles relative to uninfested ones was greater (Tables 4 and 5) than the percent reduction in the weights of full grains in infested panicles relative to uninfested panicles (Tables 6 and 7). In 1982, Gui-Chao had the smallest reduction in the number (45.5%) and weight (26.9%) of full grains which were 8 and 10% less in numbers and weights, respectively, than the next least damaged line. In contrast, the cultivar, Starbonnet, had a 82.3% reduction in number (Table 4) and a 64.1% reduction in weight (Table 6) of full grains per panicle.

In 1983, more lines (Tables 5 and 7) appeared less damaged by RSB compared to 1982 (Tables 4 and 6). Infested lines of RU 830312, RU 820134, Madew (tall plant type), Lebonnet and Skybonnet had less than a 25% reduction in full grains per panicle (Table 5). In

Table 2. Percent pecky kernels in selected rice lines infested with three pairs of field-collected rice stink bug adults for 9 days. Crowley, LA, 1981.

	% Pecky kernels/ panicle ($\bar{X}$ ± SE)				
Rice line	n	Uninfested	n	Infested	Adjusted infested[a]
Early Wataribune	16	7.3 ± 2.1	22	10.0 ± 2.1	2.9
M101	22	1.2 ± 0.6	23	4.3 ± 0.7	3.1
Century Patna 231	23	1.2 ± 0.9	25	5.6 ± 1.2	4.5
Calrose	17	2.1 ± 0.4	24	11.5 ± 1.4	9.6
Stg 69M5164	6	1.0 ± 0.7	6	12.3 ± 1.8	11.4
Carolina Gold	18	2.5 ± 0.8	24	14.9 ± 2.5	12.7
Stg 70M7046	3	2.3 ± 1.6	4	17.9 ± 6.3	16.0
Stg 70M3901	6	1.1 ± 1.1	5	18.0 ± 6.3	17.1
Stg 71M11309	4	1.7 ± 0.6	4	20.6 ± 4.0	19.2
Saturn	22	1.4 ± 0.4	21	21.6 ± 2.4	20.5

[a] Infested adj. for uninfested = $\frac{\bar{X}\text{ Uninfested} - \bar{X}\text{ Infested}}{100 - \bar{X}\text{ Uninfested}} \times 100.$

Table 3. Percent undamaged kernels in selected rice lines infested with three pairs of field-collected rice stink bug adults for 9 days. Crowley, LA, 1981.

	% Undamaged kernels/ panicle ($\bar{X}$ ± SE)				
Rice line	n	Uninfested	n	Infested	Reduction of uninfested[a]
Stg 71M11309	4	82.4 ± 3.0	4	50.8 ± 6.8	38.3
Stg 70M7046	3	87.1 ± 4.0	4	34.7 ± 9.3	60.2
Saturn	22	77.5 ± 2.9	21	28.9 ± 2.9	62.7
Stg 69M5164	6	84.1 ± 4.2	6	28.5 ± 8.1	66.1
Stg 70M3901	6	86.2 ± 3.8	5	28.2 ± 4.6	67.3
Carolina Gold	18	85.8 ± 2.0	24	27.4 ± 3.6	68.1
Early Wataribune	16	67.0 ± 4.9	22	15.5 ± 1.9	76.9
Calrose	17	90.3 ± 1.3	24	18.1 ± 2.9	80.0
Century Patna 231	23	80.1 ± 2.8	25	13.5 ± 2.7	83.1
M101	22	72.6 ± 2.5	23	2.5 ± 0.5	96.6

[a] Reduction of uninfested = $\frac{\bar{X}\text{ Uninfested} - \bar{X}\text{ Infested}}{\bar{X}\text{ Uninfested}} \times 100$.

Table 4. Percent full grains[a] in uninfested and infested panicles[b] of 37 rice lines evaluated for resistance to the rice stink bug. Crowley, LA, 1982.

		% Full grains/ panicle ($\bar{X}$ ± SE)		
1982 Disease Nursery No.	Line	Uninfested[c]	Infested[c]	Reduction of uninfested[d]
558	Gui-Chao	82.6 ± 0.5	45.0 ± 13.5	45.5
	PI 353441	57.5 ± 1.4	26.9 ± 8.2	53.2
	"Shoemed"[e]	74.2 ± 0.1	31.8 ± 6.3	57.1
	RU 7803070	64.1 ± 2.9	26.9 ± 10.7	58.0
551	Cica 6	80.0 ± 11.4	33.3 ± 5.2	58.4
555	CR 1113	92.6 ± 0.3	37.3 ± 0.3	59.7
554	Cica 9	73.6 ± 6.3	29.5 ± 2.9	59.9
515	IR 20 (81/D-24)	65.5 ± 5.2	25.4 ± 2.6	61.2
557	Fan 1	93.7[f]	33.7[f]	64.0
562	Yo-Ke	98.0 ± 0.1	31.4 ± 6.6	68.0
563	Minehikari	94.9 ± 0.6	32.3 ± 17.7	66.0
564	Taipai 309	73.9 ± 11.8	24.8 ± 5.1	66.4
550	Cica 4	84.0 ± 0.4	27.3 ± 6.4	67.5
	PI 247890	77.3 ± 2.1	24.8 ± 9.3	68.0
674	N #1/H_4	74.2 ± 7.1	21.3 ± 2.5	71.3
	PI 185811	75.0[f]	21.1 ± 9.0	71.9
	PI 373693	70.0 ± 1.1	18.6 ± 14.3	73.4
260	LBNT/9902	60.4 ± 4.9	15.8 ± 15.8	73.8

Table 4. Continued.

		% Full grains/ panicle ($\overline{X} \pm SE$)		
1982 Disease Nursery No.	Line	Uninfested[c]	Infested[c]	Reduction of uninfested[d]
	RU 7603015	69.4 ± 2.8	17.0 ± 5.0	75.5
	PI 185810	82.5 ± 12.4	19.5 ± 14.8	76.4
677	PI 372970	74.1 ± 4.7	17.0 ± 1.7	77.1
560	Quang Lu $A_1$4	80.8 ± 1.6	18.1 ± 2.2	77.6
561	Rice X Grass	74.7 ± 4.6	16.7 ± 15.1	77.6
220	STBN/STTD	74.8 ± 8.9	16.7 ± 15.4	77.7
553	Cica 8	72.2 ± 0.7	15.7 ± 0.2	78.3
552	Cica 7	44.4 ± 11.4	8.4 ± 5.0	81.1
275	Starbonnet	61.5 ± 17.7	10.9 ± 2.9	82.3
559	Qing Qun Wang	89.8 ± 0.6	13.3 ± 8.2	85.2
565	IR 36	94.3 ± 0.8	12.8 ± 0.5	86.4
521	TTEP/IR 8 (81/D-39)	76.0 ± 4.0	10.1 ± 4.6	86.7
675	PI 372991	77.2 ± 3.0	8.4 ± 0.5	89.1
	Shoemed	76.2 ± 6.3	6.0 ± 0.9	92.1
556	Bai Zhen Long	78.0 ± 12.5	3.8 ± 2.3	95.1
679	PI 372002	55.6 ± 9.9	1.7 ± 1.7	96.9
495	PI 319513	74.9 ± 0.1	1.9 ± 1.9	97.5
680	PI 373355	58.3 ± 2.8	0.5 ± 0.5	99.1
325	9881/3315881// L201	22.1 ± 13.7	0	100.0
	PI 233081	58.2 ± 6.4	0	100.0

Table 4. Continued.

[a] % No. of full grains that sank in 9% saline solution =

$$\frac{\text{No. of sinking grains}}{\text{Total no. of grains/ panicle}} \times 100$$

[b] Infested panicles were caged for 9 days with 3 pairs of rice stink bug adults.

[c] N=2, unless noted otherwise.

[d] Reduction of uninfested = $\frac{\bar{X}\text{ Uninfested} - \bar{X}\text{ Infested}}{\bar{X}\text{ Uninfested}} \times 100.$

[e] Pubescent off-type in Shoemed.

[f] N=1.

Table 5. Percent full grains[a] in uninfested and infested panicles[b] of 57 rice lines evaluated for resistance to the rice stink bug. Crowley, LA, 1983.

		% Full grains/ panicle ($\bar{X}$ ± SE)		
1983 Disease Nursery No.	Line/ Pedigree	Uninfested[c]	Infested[c]	Reduction of uninfested[d]
12	RU 8303012 1982-304 Source	67.7 ± 6.8	71.1 ± 15.7	- 5.0
7	RU 8201034 9906/9633	56.8[e]	52.0[e]	8.4
645	Madew (tall plant type)	50.6 ± 1.2	42.0 ± 9.4	17.0
36	Lebonnet BBLE/BLPT/Dawn	77.9 ± 5.6	61.5 ± 13.3	21.0
15	Skybonnet	78.2[e]	59.1 ± 2.1	24.4
	RU 7603069 9881/331581	61.5 ± 1.6	43.9[e]	28.5
	Bellemont 9881/331581	28.6 ± 6.3	20.0 ± 5.2	30.2
9	RU 8003009 LBLE/4/BBLE/DAWN//BLPT/DAWN/3/BB50*2/JJLA	84.8 ± 11.8	59.2 ± 3.3	30.2
23	RU 8303023 1982-728 Source	70.9 ± 0.7	49.2 ± 7.4	30.6
650	Leng Kwang PI 160688	80.3 ± 3.6	52.6 ± 5.6	34.5
45	RU 8102044 TKLN/IR-8/4/RRUN*2//RRRZ/132848/3/13-D/LACR	58.8 ± 7.9	37.4 ± 11.8	36.4
641	Thankote Marsi PI 452228	81.4 ± 0.8	51.4 ± 10.6	36.9
	Newrex	65.9 ± 2.1	41.5 ± 10.5	37.0
	Belle Patna	73.8 ± 3.1	45.7 ± 15.7	38.1

Table 5. Continued.

1983 Disease Nursery No.	Line/ Pedigree	% Full grains/ panicle ($\bar{X}$ ± SE) Uninfested[c]	Infested[c]	Reduction of uninfested[d]
	CI 9881 BBLE//BLPT/Dawn	53.3 ± 2.4	32.7 ± 4.8	38.4
623	KU 91 PI 452199	11.7 ± 2.7	7.2 ± 2.3	39.0
10	RU 7801011 BN 73/9841	57.0 ± 5.4	34.3 ± 3.2	40.0
3	RU 8003005 LBLE/4/BBLE//BLPT/DAWN/3/IR-8	81.3 ± 1.4	48.3 ± 8.6	40.6
29	RU 8103029 NTAI//9545/NOVA	78.3 ± 0.3	44.4 ± 0.5	43.3
	RU 8103008 NWRX//9881/331581	56.6 ± 3.8	31.5 ± 4.9	44.5
644	Arc 6000 PI 452141	69.1 ± 3.9	38.0 ± 13.0	45.1
616	Long grain red rice	44.5 ± 13.1	24.3 ± 9.1	45.4
20	Lebonnet	74.8 ± 1.8	39.8 ± 9.9	46.9
634	Dumsiah 81 PI 452162	59.5[e]	31.1 ± 12.1	47.8
	Lemont LBNT//9881/331581	60.1[e]	29.6 ± 0.9	50.8
44	RU 8101148 9879/9633	77.7 ± 11.6	37.6 ± 24.4	51.6
	Labelle BLPT/Dawn	63.4 ± 2.6	29.9 ± 15.6	52.8
	Bluebelle	48.2 ± 5.1	22.7 ± 3.8	53.0
911	Colombia 1 PI 423837	55.0 ± 13.6	25.6 ± 5.7	53.5

Table 5. Continued.

		% Full grains/ panicle ($\bar{X}$ ± SE)		
1983 Disease Nursery No.	Line/ Pedigree	Uninfested[c]	Infested[c]	Reduction of uninfested[d]
666	Silewah PI 452222	81.0 ± 0.7	37.2 ± <0.1	54.1
652	Tadukan PI 431319	55.7 ± 1.6	25.5 ± 1.3	54.3
581	PI 331581 BBLE/TN-1	56.3 ± 4.8	25.4 ± 7.3	54.9
14	Bond	51.2 ± 13.0	21.9 ± 6.2	57.3
26	RU 8303026 1982-683 Source	69.6 ± 5.2	29.9 ± 15.1	57.7
639	Sho-nan tsan PI 452219	78.8 ± 12.7	33.1 ± 3.1	58.0
	Mars	88.0[e]	36.3 ± 2.7	58.7
660	PI 452198 Kn-1b-361-1-8-6-10 (RPKN-2)	71.1 ± 9.9	27.6 ± 2.6	61.3
601	Cica 6	88.4 ± 3.4	31.0 ± 4.7	64.9
948	Ring Around Line No. 5	39.2 ± 14.7	13.7 ± 2.1	65.1
	Lebonnet BBLE//BLPT/Dawn	67.8 ± 0.4	23.5 ± 4.1	65.4
	Dawn	75.4 ± 0.6	23.9 ± 2.2	68.4
642	Unnamed Shensi PI 452230	81.2[e]	25.1 ± 7.2	69.1
603	Gui-Chao	55.3 ± 1.6	15.2 ± 8.5	72.5
31	RU 7902030 S242/UNKN/6/RXRE/4/RXOR/3/IOLA/BROS//SHMD/FRTA/5/TN-1/7/T487/RKRO//NROS	83.4 ± 2.0	22.9 ± 12.8	72.5

Table 5. Continued.

		% Full grains/ panicle ($\bar{X}$ ± SE)		
1983 Disease Nursery No.	Line/ Pedigree	Uninfested[e]	Infested[c]	Reduction of uninfested[d]
655	PI 452181 IR 5867-50-3-2-2-1-1	90.1 ± 4.4	24.1 ± 14.8	73.2
846	Ching-Tu Hsu ID # 81/D-03	71.5 ± 5.6	16.7 ± 16.7	76.7
657	PI 452179 IR 5467-2-2-2	39.9 ± 5.0	9.1[e]	77.2
598	Cica 9	49.0 ± 1.9	9.9 ± 0.1	79.8
619	R 54 PI 452218	53.5 ± 3.5	10.6 ± 4.8	80.2
949	Ring Around Line No. 6	67.2 ± 12.7	12.5 ± 9.5	81.5
658	PI 452173 IR 10222-12-2	60.3 ± 2.8	11.0 ± 1.0	81.7
638	Pho Kha PI 452217	19.3 ± 8.9	3.1 ± 0.8	84.1
610	BR 7	61.0 ± 3.2	9.7 ± 1.1	84.1
628	PI 452183 IR 9129-204-1-2	79.0 ± 4.6	12.5 ± 0.1	84.2
609	Cica 7	60.5 ± 5.8	7.8 ± 2.3	87.2
602	Cica 4	66.8 ± 6.9	2.9 ± 0.3	95.7
630	Shinriki PI 452220	58.8 ± 7.4	0	100.0

[a] % Full grains in a panicle that sank in 9% saline solution =

$$\frac{\text{No. of sinking grains}}{\text{Total no. of grains/ panicle}} \times 100$$

Table 5. Continued.

[b] Infested panicles were caged for 9 days with 3 pairs of rice stink bug adults.

[c] N=2, unless noted otherwise.

[d] Reduction of uninfested = $\frac{\bar{X}\text{ Uninfested} - \bar{X}\text{ Infested}}{\bar{X}\text{ Uninfested}}$ X 100.

[e] N=1.

Table 6. Percent full grain weight[a] in uninfested and infested panicles[b] of 37 rice lines evaluated for resistance to the rice stink bug. Crowley, LA, 1982.

		% Full grain wt./ panicle wt. ($\overline{X} \pm SE$)		
1982 Disease Nursery No.	Line	Uninfested[c]	Infested[c]	Reduction of uninfested[d]
558	Gui-Chao	89.8 ± 1.6	65.6 ± 11.9	26.9
551	Cica 6	93.1 ± 1.4	56.6 ± 2.1	36.4
554	Cica 9	92.3 ± 2.6	56.5 ± 0.2	38.8
	PI 353441	78.8 ± 1.8	48.1 ± 9.2	39.0
	RU 7803070	87.8 ± 3.0	53.5 ± 12.7	39.1
564	Taipai 309	83.4 ± 9.2	50.7 ± 6.7	39.2
515	IR 20 (81/D-24)	85.8 ± 2.8	52.0 ± 3.9	39.4
555	CR 1113	97.7 ± 0.4	56.2 ± 0.6	42.5
563	Minehikari	98.0 ± 0.4	53.6 ± 19.3	45.3
557	Fan 1	97.9[e]	53.4[e]	45.5
	"Shoemed"[f]	90.8 ± 0.5	48.7 ± 3.9	46.4
674	N #1/H_4	89.3 ± 3.0	47.4 ± 5.8	46.9
562	Yo-Ke	99.6 ± 0.6	52.4 ± 7.9	47.4
550	Cica 4	95.0 ± 0.4	49.6 ± 10.3	47.8
	PI 185811	91.3[e]	42.9 ± 13.9	53.0
	RU 7603015	90.4 ± 2.6	41.9 ± 6.1	53.7
	PI 247890	90.7 ± 0.6	39.8 ± 10.7	56.1
553	Cica 8	89.5 ± 0.5	38.4 ± 1.2	57.1
	PI 185810	91.6 ± 5.5	38.3 ± 24.6	58.2

Table 6. Continued.

		% Full grain wt./ panicle wt. ($\bar{X}$ ± SE)		
1982 Disease Nursery No.	Line	Uninfested[c]	Infested[c]	Reduction of uninfested[d]
561	Rice X Grass	84.6 ± 3.0	33.3 ± 27.6	60.6
677	PI 372970	86.1 ± 5.7	31.6 ± 0.5	63.3
	PI 373693	85.5 ± 0.9	31.0 ± 18.6	63.7
275	Starbonnet	82.9 ± 9.8	29.8 ± 6.5	64.1
560	Quang Lu $A_1$4	93.0 ± 2.8	33.2 ± 3.3	64.3
552	Cica 7	64.7 ± 7.9	23.0 ± 10.7	64.5
565	IR 36	98.0 ± 0.4	34.2 ± 3.1	65.1
220	STBN/STTD	91.8 ± 1.6	31.7 ± 26.7	65.6
260	LBNT/9902	83.2 ± 5.0	28.5 ± 28.5	65.7
675	PI 372991	93.8 ± 0.9	28.4 ± 1.4	69.7
559	Qing Qun Wang	96.2 ± 1.7	26.2 ± 10.7	72.8
521	TTEP/IR 8 (81/D-39)	92.2 ± 1.5	24.5 ± 8.2	73.4
	Shoemed	89.7 ± 5.4	16.3 ± 1.3	81.8
556	Bai Zhen Long	89.3 ± 8.6	12.5 ± 6.1	86.0
495	PI 319513	90.7 ± 0.6	7.5 ± 7.5	91.7
679	PI 372002	80.1 ± 1.2	4.4 ± 4.4	94.5
680	PI 373355	86.8 ± 3.2	1.7 ± 1.7	98.0
325	9881/3315881// L201	39.2 ± 21.8	0	100.0
	PI 233081	74.7 ± 2.2	0	100.0

Table 6. Continued.

[a] % Wt. of full grains that sank in 9% saline solution = $\frac{\text{Wt. of sinking grains}}{\text{Total wt. of grains/ panicle}}$ X 100.

[b] Infested panicles were caged for 9 days with 3 pairs of rice stink bug adults.

[c] N=2, unless noted otherwise.

[d] Reduction of uninfested = $\frac{\bar{X}\text{ Uninfested} - \bar{X}\text{ Infested}}{\bar{X}\text{ Uninfested}}$ X 100.

[e] N=1.

[f] Pubescent off-type in Shoemed.

addition to the above five lines, 12 lines including Bellemont, Newrex, Belle Patna and CI 9881 had less than a 26% reduction in the weights of full grains per panicle (Table 7).

Results of lines screened for RSB resistance for both years are summarized in Table 8. The "resistance" observed in Gui-Chao in 1982 was not apparent in 1983. Except for RU 7603015 (Skybonnet), lines appeared to be more damaged in 1983 than in 1982.

DISCUSSION

RSB injury to rice grains is characterized by light-weight grains and pecky kernels. The percentage of undamaged grains in a panicle, which can be estimated by the grains that sink in 9% saline solution, can be used to evaluate tolerance in rice. Either weights or numbers of sinking (full) grains can be used. Though the percentages of weights and numbers of full grains per panicle were highly correlated ($P < 0.0001$) in both uninfested (1982: $r = 0.91$, $n = 76$; 1983: $r = 0.90$, $n = 108$) and infested panicles (1982: $r = 0.96$, $n = 75$; 1983: $r = 0.96$, $n = 111$) across all lines tested, evaluations using both methods did not give similar results for lines with less than 26% damage. Therefore, either weights or numbers should be used consistently.

Nilakhe (1976b) had found that infested panicles of the breeding lines, Stg 70M7046, Stg 69M5164, Stg 71M11309 and Stg 70M3901, weighed only 2.0 to 2.9 mg less per grain than uninfested panicles. Re-evaluation results of these lines in 1981 indicated that infested Stg 71M11309 panicles were less damaged than infested panicles of the other three lines (Table 3), and the percent pecky kernels was much

Table 7. Percent full grain weight[a] in uninfested and infested panicles[b] of 57 rice lines evaluated for resistance to the rice stink bug. Crowley, LA, 1983.

		% Full grain wt./ panicle wt. ($\bar{X}$ ± SE)		
1983 Disease Nursery No.	Line/ Pedigree	Uninfested[c]	Infested[c]	Reduction of uninfested[d]
12	RU 8303012 1982-304 Source	86.7 ± 5.4	86.0 ± 9.7	0.8
623	KU 91 PI 452199	15.5 ± 3.5	14.3 ± 2.5	7.6
36	Lebonnet BBLE//BLPT/Dawn	91.4 ± 0.8	83.9 ± 9.1	8.3
7	RU 8201034 9906/9633	76.9[e]	69.6[e]	9.6
15	Skybonnet	93.5[e]	82.7 ± 1.7	11.6
9	RU 8003009 LBLE/4/BBLE/DAWN//BLPT/DAWN/3/BB50*2/JJLA	92.2 ± 7.0	79.8 ± 1.8	13.4
	RU 7603069 9881/331581	85.5 ± 0.1	72.2[e]	15.5
23	RU 8303023 1982-728 Source	87.3 ± 1.7	73.3 ± 6.8	16.0
650	Leng Kwang PI 160688	90.2 ± 1.5	74.3 ± 7.3	17.7
	Bellemont 9881/331581	55.8 ± 4.1	45.0 ± 8.5	19.2
	Newrex	88.2 ± 0.3	68.1 ± 12.8	22.9
29	RU 8103029 NTAI//9545/NOVA	89.1 ± 1.1	68.0 ± 1.4	23.7
645	Madew (tall plant type)	82.8 ± 3.4	62.4 ± 8.2	24.6

Table 7. Continued.

1983 Disease Nursery No.	Line/ Pedigree	% Full grain wt./ panicle wt. ($\bar{X}$ ± SE) Uninfested[c]	Infested[c]	Reduction of uninfested[d]
	CI 9881 BBLE//BLPT/Dawn	79.8 ± 3.4	59.8 ± 4.8	25.1
641	Thankote Marsi PI 452228	93.7 ± 0.5	69.9 ± 7.8	25.4
3	RU 8003005 LBLE/4/BBLE//BLPT/DAWN/3/IR-8	94.0 ± 0.8	70.1 ± 4.1	25.5
	Belle Patna	88.8 ± 0.4	66.1 ± 9.5	25.5
20	Lebonnet	89.7 ± 0.6	66.5 ± 8.6	25.9
45	RU 8102044 TKLN/IR-8/4/RRUN*2//RRRZ/132848/3/13-D/LACR	83.6 ± 3.0	59.0 ± 10.5	29.4
911	Colombia 1 PI 423837	70.6 ± 12.7	48.9 ± 9.1	30.7
10	RU 7801011 BN 73/9841	81.8 ± 1.0	56.6 ± 1.5	30.8
	Lemont LBNT//9881/331581	82.2[e]	56.6 ± 3.6	31.1
644	Arc 6000 PI 452141	85.5 ± 1.9	58.6 ± 13.7	31.5
616	Long grain red rice	73.4 ± 11.7	48.8 ± 9.6	33.5
	RU 8103008 NWRX//9881/331581	83.3 ± 4.3	55.4 ± 2.6	33.5
44	RU 8101148 9879/9633	88.3 ± 5.9	58.4 ± 24.8	33.9
26	RU 8303026 1982-683 Source	84.0 ± 2.9	54.9 ± 15.1	34.6

Table 7. Continued.

1983 Disease Nursery No.	Line/ Pedigree	% Full grain wt./ panicle wt. ($\bar{X}$ ± SE) Uninfested[c]	Infested[c]	Reduction of uninfested[d]
581	PI 331581 BBLE/TN-1	82.6 ± 4.4	51.9 ± 8.6	37.1
	Labelle BLPT/Dawn	87.6 ± 3.5	52.8 ± 19.6	39.7
642	Unnamed Shensi PI 452230	90.7[e]	54.5 ± 9.4	39.9
639	Sho-nan tsan PI 452219	88.1 ± 6.6	52.5 ± 0.7	40.5
666	Silewah PI 452222	92.3 ± 1.8	54.8 ± 1.1	40.6
660	PI 452198 Kn-1b-361-1-8-6-10 (RPKN-2)	88.9 ± 4.0	52.2 ± 0.1	41.2
652	Tadukan PI 431319	82.0 ± 3.1	47.4 ± 1.2	42.2
	Bluebelle	80.1 ± 4.4	45.7 ± 7.5	43.0
14	Bond	76.4 ± 8.7	42.9 ± 10.2	43.9
	Mars	94.9[e]	53.0 ± 1.7	44.1
	Lebonnet BBLE//BLPT/Dawn	88.4 ± 0.3	46.9 ± 3.2	47.0
601	Cica 6	95.3 ± 3.0	50.4 ± 5.8	47.1
634	Dumsiah 81 PI 452162	86.2[e]	45.0 ± 6.4	47.8
	Dawn	90.0 ± 1.1	46.5 ± 2.0	48.3
948	Ring Around Line No. 5	58.0 ± 18.3	26.8 ± 3.8	53.9
31	RU 7902030 S242/UNKN/6/RXRE/4/RXOR/3/IOLA/BROS//SHMD/FRTA/5/TN-1/7/ T487/RKRO//NROS	89.6 ± 2.2	40.9 ± 19.0	54.4

Table 7. Continued.

		% Full grain wt./ panicle wt. ($\bar{X}$ ± SE)		
1983 Disease Nursery No.	Line/ Pedigree	Uninfested[c]	Infested[c]	Reduction of uninfested[d]
655	PI 452181 IR 5867-50-3-2-2-1-1	96.0 ± 1.9	42.8 ± 15.3	55.4
628	PI 452183 IR 9129-204-1-2	94.0 ± 1.9	41.0 ± 2.8	56.5
603	Gui-Chao	81.0 ± 0.2	34.2 ± 9.2	57.7
658	PI 452173 IR 10222-12-2	85.4 ± 1.7	33.6 ± 2.3	60.6
619	R 54 PI 4522180	72.0 ± 1.8	28.0 ± 9.0	61.1
598	Cica 9	76.4 ± 1.3	25.3 ± 1.4	66.8
846	Ching-Tu Hsu ID # 81/D-03	86.2 ± 1.9	27.9 ± 27.9	67.6
657	PI 452179 IR 5467-2-2-2	64.7 ± 2.5	20.2[e]	68.9
949	Ring Around Line No. 6	85.7 ± 4.5	26.6 ± 18.8	68.9
610	BR 7	83.2 ± 3.5	24.1 ± 2.3	71.0
609	Cica 7	77.7 ± 5.1	22.3 ± 7.8	71.3
638	Pho Kha PI 452217	26.0 ± 10.7	6.3 ± 0.3	75.6
602	Cica 4	84.6 ± 4.1	9.1 ± 1.4	89.2
630	Shinriki PI 452220	76.5 ± 8.0	0	100.0

[a] % Wt. of full grains that sank in 9% saline solution =

$$\frac{\text{Wt. of sinking grains}}{\text{Total wt. of grains/ panicle}} \times 100$$

Table 7. Continued.

[b] Infested panicles were caged for 9 days with 3 pairs of rice stink bug adults.

[c] N=2, unless noted otherwise.

[d] Reduction of uninfested = $\frac{\bar{X}\text{ Uninfested} - \bar{X}\text{ Infested}}{\bar{X}\text{ Uninfested}}$ X 100.

[e] N=1.

Table 8. Percent reduction[a] in the numbers[b] and weights[c] of full rice grains of uninfested panicles when panicles were infested[d] with rice stink bug adults[e]. Crowley, LA, 1982 and 1983.

	% Reduction of uninfested panicles.					
	Full grains/ panicle			Full grain wt./ panicle wt.		
Line	1982	1983	$\bar{X} \pm SE$[f]	1982	1983	$\bar{X} \pm SE$[f]
RU7603015 (Skybonnet)	75.5	24.4	50.0 ± 25.6	53.7	11.6	32.7 ± 21.1
Gui-Chao	45.5	72.5	59.0 ± 13.5	26.9	59.7	42.3 ± 15.4
Cica 6	58.4	64.9	61.7 ± 3.3	36.4	47.1	41.8 ± 5.4
Cica 4	67.5	95.7	81.6 ± 6.4	47.8	89.2	68.5 ± 20.7
Cica 7	81.1	87.2	84.2 ± 3.0	64.5	71.3	67.9 ± 3.4

[a] % Reduction/ panicle = $\frac{\text{Uninfested - Infested}}{\text{Uninfested}}$ X 100.

[b] % full grains that sank in 9% saline solution = $\frac{\text{No. of sinking grains}}{\text{Total no. of grains/ panicle}}$ X 100.

[c] % Wt. of full grains that sank in 9% saline solution = $\frac{\text{Wt. of sinking grains}}{\text{Total wt. of grains/ panicle}}$ X 100.

[d] Infestation dates: RU7603015; 24 Aug. 1982 and 1 Sept. 1983
Gui-Chao; 18 Aug. 1982 and 31 Aug. 1983
Cica 6; 18 Aug. 1982 and 31 Aug. 1983
Cica 4; 26 Aug. 1982 and 8 Sept. 1983
Cica 7; 19 Sept. 1982 and 8 Sept. 1983.

[e] Infested panicles were caged for 9 days with 3 pairs of rice stink bug adults.

[f] N=2.

lower for all four lines (Table 2) than the 87.1 to 100.0% reported by Nilakhe (1976b). The large differences in percent pecky kernels in the two evaluations can be attributed to the different methods used to measure pecky kernels.

The response of lines to RSB infestation varied over a wide range and two replications for each treatment within a line were insufficient to detect statistical differences. Small number of replications allowed more lines to be tested but the chances were greater for tolerant lines to appear susceptible because of differential response to environmental stresses such as temperature extremes, poor fertilization, diseases and other insects. 'Lebonnet' was evaluated three times in 1983 and the results of infested panicles were very variable. 'Lebonnet' in plots 20 and 36 were infested at the same date and were located in the same block. The differences in numbers and weights of full grains were small (less than 3%) for uninfested panicles but differed by more than 17% for infested panicles. Uninfested 'Lebonnet' panicles evaluated 17 days later did not differ greatly (less than 10%) in number or weight of full grains compared to those tested earlier. However infested 'Lebonnet' panicles were even more damaged than panicles infested earlier. Response of rice lines to RSB infestation may vary both in time and space. At each time of infestation, standard lines, preferably both resistant and susceptible, should also be included. These lines should be consistent from year to year and be of different maturity groups to allow relative comparisons.

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CHAPTER VI

EVALUATION OF PENN-CAP M FOR RICE STINK BUG CONTROL IN RICE

This chapter is written in the style of the
Journal of Economic Entomology

ABSTRACT

Penn-cap M (0.3 kg AI/ ha), an encapsulated formulation of methyl parathion, provided better control of caged pairs of adult rice stink bugs (RSB), *Oebalus pugnax* (F.), than methyl parathion EC (0.3 kg AI/ ha). When adults were caged 4 hours after insecticide application, 24-hour mortality was much higher in Penn-cap M than in Sevin XLR (1.1 kg AI/ ha) plots. Sevin XLR had better residual control than Penn-cap M or methyl parathion at 48 hours after application. No differences in mortality were found in both untreated and treated plots after 72 hours after application. Mortality of caged RSB females was significantly lower than that of males. Natural infestation levels were very low in all plots so comparison of insecticide performance based on sweep-net counts were not made.

INTRODUCTION

The rice stink bug (RSB), *Oebalus pugnax* (F.), is a pest of rice in the southern United States. Both adults and nymphs feed on developing rice grains. Grains fed upon early in development abort or fail to fill while grains punctured in the later dough stages often result in "pecky rice". Pecky rice are kernels with large chalky or discolored lesions with a small puncture near the center. The lesions may darken when invaded by field fungi. Damaged grains are structurally weakened and often break during milling, reducing the yield of head (unbroken) rice. Damaged unbroken kernels in samples can reduce the grade and lower the price received per cwt. (Swanson & Newsom 1962, Brorsen, et al. 1984, Fryar et al. 1986).

In Louisiana, current action thresholds are 50 RSB per 100 sweeps during the first two weeks of heading, and afterwards 100 bugs per 100 sweeps until two weeks before harvest (Anon. 1986). Several insecticides are available for population suppression. In this study, the short and long term toxicity of Penn-cap M (encapsulated methyl parathion) was compared to the currently recommended insecticides in Louisiana.

METHODS AND MATERIALS

The following insecticides at rates recommended for RSB control in Louisiana were evaluated along with an untreated control: Penn-cap M (0.2 kg methyl parathion/ liter) @ 0.3 kg AI/ ha, methyl parathion EC (0.5 kg methyl parathion/ liter) @ 0.3 kg AI/ ha, and Sevin XLR (0.5 kg carbaryl/ liter) @ 1.1 kg AI/ ha. On 26 September 1983, drill-seeded headed rice in 1.2 m X 4.9 m-plots was sprayed at 6.5 km/ hr with a hand-held boom fitted with FL2 T-Jett nozzles at 4.5 kg/ cm^2 (CO_2) to deliver 186.9 liter of diluted insecticide per hectare. Each insecticide was applied to one plot in each of the three blocks.

Sweep-net counts of RSB were taken immediately prior to and 4, 24, 48 and 72 hours after insecticide application. Thirty sweeps per plot were made using a 38.1-cm diameter net, and the number of females, males and nymphs in a plot within a block were recorded. RSB adults collected from headed grasses were caged on treated panicles with nylon tulle cages (30.3 cm long, 7.5 cm wide and 64 openings/ cm^2) at a rate of three pairs per panicle with three replications per treatment within a plot. RSB adults were caged 4, 24, 48 and 72 hours after insecticide application and mortality of females and males was recorded approximately 24 hours after each infestation time.

The number of RSB adults caught per plot was analyzed as a randomized complete block design with three factors; insecticide treatment, time of infestation and sex. Mortality of caged RSB females and males was calculated as a percentage of the three insects per sex initially confined to the panicle. Percentage data were transformed using the arcsine square root transformation. The data were analyzed as a split-split-split plot design with insecticide treatments as the whole plot, sex as the sub-plot and time of infestation as the sub-sub plot (SAS Institute 1982). Significant treatment and simple interaction means were examined with the LSD test (Little & Hills 1978).

RESULTS

Sweep-net Method. The number of RSB adults and nymphs caught per plot was very low both before and after insecticide application. The average number of adult RSB per plot ranged from 0.5 (± 0.25 SE) to 1.2 (± 0.7) prior to insecticide application. After treatment, the average number of RSB adults per plot ranged from 0 to 0.3 (± 0.02). Because the numbers of natural populations of RSB were so low, comparisons among insecticides for RSB control were not made.

Cage Tests. RSB adult mortality was affected by both the insecticide treatment and the time of infestation ($P < 0.002$; Appendix D, Table D1). When insects were caged 4 and 24 hours after insecticide application, mortality varied significantly ($P \leq 0.05$)

with the insecticide treatment (Table 1). No differences ($P > 0.05$) in mortality were found among insecticide treatments including the untreated control when insects were infested 48 and 72 hours after insecticide application.

Among RSB adults caged 4 hours after insecticide application, mortality was the highest ($P \leq 0.05$) in plots treated with Penn-cap M plots (Table 1). Mortality in plots treated with Sevin XLR and methyl parathion plots was similar ($P > 0.05$) but was greater ($P \leq 0.05$) than the untreated control. When insects were caged 24 hours after insecticide application, the highest mortality occurred in Sevin XLR plots ($P \leq 0.05$) (Table 1). Mortality in Penn-cap M, methyl parathion and untreated plots was similar ($P > 0.05$) though the mortality in Penn-cap M plots was almost twice that observed in methyl parathion plots.

Within an insecticide treatment, RSB mortality was affected by the time of infestation ($P < 0.002$; Appendix D, Table D1). No differences ($P > 0.05$) in mortality were observed in the untreated control at all times of infestation or in the insecticide-treated plots when RSB were infested 48 and 72 hours after insecticide application (Table 1). In Penn-cap M and methyl parathion plots, the highest mortality occurred when insects were infested 4 hours after insecticide treatment, and declined significantly ($P \leq 0.05$) when infestation occurred 24 hours later. The opposite trend was observed in Sevin XLR plots ($P \leq 0.05$).

Mortality was also affected by the sex of the insect (Appendix D, Table D1). Female RSB had almost 10% less mortality ($P < 0.004$) than males (53.0 ± 3.24 and 64.43 ± 3.17, $n = 144$, respectively).

Table 1. Mortality of field-collected rice stink bug adult pairs[a] caged at different times after insecticide application and exposed to treated panicles for 24 hours. Crowley, LA, 1983.

Insecticide	% Mortality ($\bar{X}$ ± SE) when caged			
	4 hrs. after insect. appl.	24 hrs. after insect. appl.	48 hrs. after insect. appl.	72 hrs. after insect. appl.
Penn-cap M (0.3 kg AI/ ha)	79.6 ± 7.2 aA	35.2 ± 8.7 bB	3.7 ± 2.5 c	9.3 ± 5.3 c
Sevin XLR (0.3 kg AI/ ha)	33.3 ± 10.8 bB	48.1 ± 9.0 aA	27.8 ± 8.2 b	11.1 ± 4.7 b
Me-Parathion (1.1 kg AI/ ha)	44.4 ± 8.1 aB	18.5 ± 5.5 bB	9.3 ± 4.5 b	3.7 ± 2.5 b
Untreated	5.6 ± 3.0 C	18.5 ± 5.5 B	5.6 ± 3.0	7.4 ± 3.4

Means followed by a different lower case letter in the same row are significantly different, LSD = 24.57, $P \leq 0.05$. Means followed by a different upper case letter in the same column are significantly different, LSD = 26.90, $P \leq 0.05$. $P < 0.002$ for the insecticide by infestation time interaction.

[a] Three pairs of rice stink bugs were caged on each panicle. N = 18 panicles for each insecticide treatment by infestation time combination.

Mortality of each sex did not appear to be affected by the insecticide treatment ($P > 0.80$; Appendix D, Table D1).

DISCUSSION

Penn-cap M (0.3 kg AI/ ha) provided better adult RSB control than the unencapsulated methyl parathion (0.3 kg AI/ ha) for up to 48 hours after application. Penn-cap M had less residual control than Sevin XLR (0.5 kg AI/ ha) at 48 hours after application, but was more toxic to RSB when they were exposed soon after application. The increase in RSB mortality in Sevin XLR plots infested 24 hours after insecticide application when compared to mortality of insects infested earlier may not be significant considering the almost three-fold increase in mortality in the untreated control. All insecticides had lost their effectiveness 72 hours after application. No rain fell during the test period.

Insecticide evaluations based on mortality of caged insects on treated panicles are less dependent on seasonal numbers of RSB than sweep-net counts and tests can be conducted when natural populations are declining. In this study, evaluation of insecticide performance was not possible using sweep-net counts because of the low natural population of RSB adults and nymphs at the end of September. In cage tests, insects can be collected elsewhere and brought into the treated area. The insects are confined in cages and cannot move out of the sampling area or into other treated areas. Insects of a particular developmental stage and sex can be easily tested in cages.

For all treatments in this study, caged females were found to live longer than caged males. Often sweep-net count data from previous tests in the literature do not distinguish the numbers of females and males caught (Oliver et. al. 1972, Bowling 1962). population structure of RSB varies in time and space so nymphs, females and males are not present in equal numbers. To make meaningful comparisons among insecticide treatments, data should designate the sex or instar of the insect as well.

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CONCLUSIONS

Light-weight grains and spotted (pecky) kernels often result from rice stink bugs (RSB), Oebalus pugnax (F.) feeding on developing rice grains. Examinations of kernels and hulls of grains with feeding sheaths (flanges) showed that fungal pathogens can use punctures to enter kernels. However, the presence of a feeding sheath does not necessarily indicate the hull or kernel has been punctured. More studies are needed to determine whether feeding-sheath counts can reliably detect antixenosis in rice to RSB.

The broad-spectrum fungicide, propriconazol, was nontoxic to RSB adults at recommended application rates. Full grain weights of uninfested-caged rice panicles and panicles infested with one and two RSB adult pairs were reduced by both fungal pathogens and insects. The percent pecky kernels among full grains in infested panicles were affected only by the insects. Under endemic disease conditions, the percentage of pecky kernels was affected by the RSB infestation rate and the rice line.

Encapsulated methyl parathion, methyl parathion and carbaryl are currently recommended for control of RSB in Louisiana. Encapsulated methyl parathion provided superior control of RSB adults within 24 hours after application compared to the unencapsulated formulation. Carbaryl remained active a day longer than either formulation of methyl parathion. All insecticides lost activity after 72 hours after application. Males were found to have higher mortality than females and this fact should be considered in future evaluation studies.

The search for rice lines tolerant to RSB injury will be aided by a technique which uses a saturated saline solution to separate damaged from undamaged rice grains. Because tolerance RSB injury can be masked by other environmental stresses, rice lines should be evaluated under as ideal growing conditions as possible. One method of evaluation would be to infest lines in the early milk stage with three RSB adult pairs for five days. More than two replications for each infested and uninfested-caged treatment are needed to make statistical comparisons ($P \leq 0.05$). The evaluation method used in this study can be adapted to identify RSB resistance in the more than 40,000 entries of rice germplasm.

APPENDIX A

Appendix Table A1. Analysis of variance of the cumulative percent mortality[a] of field-collected rice stink bug adult pairs caged for 120 hours on Saturn rice panicles previously treated with varying concentrations of the fungicide, propriconazol. Crowley, LA, 1982.

Source	df	Type III SS	F value	Pr > F
Block	1	< 0.01	0.31	0.5851
Dose[b]	5	0.29	1.08	0.3992
Block X Dose	5	0.01	0.37	0.8666
Error	23	0.13		

[a] ANOVA was calculated using PROC GLM (SAS Institute 1982). Because the ANOVA of arcsine square root transformed data was almost identical to the ANOVA of the untransformed data, the results of the untransformed data are reported.

[b] Panicles were sprayed until run-off (10 squirts) with either water, 1000, 2500, 5000, 7500 or 10000 ppm solution of propriconazol.

Appendix Table A2. Analysis of variance of the cumulative percent mortality of field-collected rice stink bug (RSB) adult pairs on Saturn rice panicles treated with propriconazol[a]. Crowley, LA, 1982.

Source	df	Type III SS	F value	Pr > F
Time[b]	2	0.39	4.75	0.0122
Dose[c]	1	0.01	0.22	0.6420
Time X Dose	2	0.03	0.33	0.7195
Sex	1	2.23	53.75	0.0001
Time X Sex	2	0.62	0.75	0.4771
Dose X Sex	1	0.14	3.26	0.0761
Time X Sex X Dose	2	0.05	0.63	0.5360
Error	60	2.49		

[a] ANOVA was calculated using PROC GLM (SAS Institute 1982). Data were transformed by taking the arcsine square root.

[b] Cumulative mortality was taken 24, 48 and 96 hours after introduction of 5 RSB adult pairs into 250-ml glass jars containing two treated panicles.

[c] Panicles were dipped in water or a 10,000 ppm solution of propriconazol and allowed to air dry before being placed into jars.

APPENDIX B

Appendix Table B1. Analysis of variance for the weights of sinking (full) grains[a] in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with rice stink bug (RSB) adults at densities ranging from caged 0 to 5 pairs per panicle. Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[b]	6	28.0937	11.84	0.0001
RSB density	5	117.8942	90.00	0.0001
fungicide	1	10.3474	26.18	0.0001
RSB density X fungicide	5	7.2808	3.68	0.0028
cultivar	2	9.3709	11.85	0.0001
RSB density X cultivar	10	2.8380	0.72	0.7078
fungicide X cultivar	2	0.6323	0.80	0.4501
RSB density X fungicide X cultivar	10	1.2892	0.33	0.9741
error	437	172.7516		

[a] Grains in a panicle that sank in 9% saline solution.

[b] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 4 blocks; 1983, 3 blocks).

Appendix Table B2. Analysis of variance for the transformed[a] percent number of spotted kernels among sinking (full) grains[b] in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with rice stink bug (RSB) adults at densities ranging from caged 0 to 5 pairs per panicle. Crowley, LA, 1982.

Source	df	Type III sums of squares	F value	Pr > F
block	3	0.0323	0.33	0.8020
RSB density	5	0.5710	3.52	0.0043
fungicide	1	0.0246	0.76	0.3845
RSB density X fungicide	5	0.3865	2.38	0.0391
cultivar	2	0.3697	5.70	0.0038
RSB density X cultivar	10	0.2660	0.82	0.6091
fungicide X cultivar	2	0.0728	1.12	0.3269
RSB density X fungicide X cultivar	10	0.2554	0.79	0.6406
error	269	9.48		

[a] Data were transformed by taking the arcsine square root of the % number of spotted kernels among full grains in a panicle.

[b] Grains in a panicle that sank in 9% saline solution.

Appendix Table B3. Analysis of variance for the transformed[a] percent number of spotted kernels among sinking (full) grains[b] in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with 0 and 3 pairs of rice stink bug (RSB) adults. Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[c]	6	0.2403	2.66	0.0176
RSB density	1	0.4405	29.31	0.0001
fungicide	1	0.0000	0.00	0.9720
cultivar	2	0.1834	6.10	0.0029
RSB density X cultivar	2	0.0352	1.17	0.3126
fungicide X cultivar	2	0.0952	3.17	0.0451
RSB density X fungicide	1	0.0140	0.93	0.3355
RSB density X fungicide X cultivar	2	0.0214	0.71	0.4924
error	141	2.1187		

[a] Data were transformed by taking the arcsine square root of the % number of spotted kernels among full grains in a panicle.

[b] Grains in a panicle that sank in 9% saline solution.

[c] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 4 blocks; 1983, 3 blocks).

Appendix Table B4. Analysis of variance for the weights of sinking (full) grains[a] in panicles of four rice lines infested with rice stink bugs (RSB) at 0, 10 and 20 days after flowering for 0, 30 and 60 bug days[b]. Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[c]	7	4.5763	1.25	0.2738
bug days	2	88.1723	84.44	0.0001
line	3	1.0321	0.66	0.5779
bug days X line	6	3.0130	0.96	0.4512
days after flowering	2	75.5525	72.36	0.0001
bug days X days after flowering	4	35.3280	16.92	0.0001
line X days after flowering	6	5.5123	1.76	0.1069
bug days X line X days after flowering	12	2.1372	0.34	0.9810
error	319	166.5484		

[a] Grains in a panicle that sank in 9% saline solution.

[b] 0, 30 and 60 bug days represent 0 and 3 pairs of RSB adults feeding for 5 and 10 days, respectively.

[c] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 5 blocks; 1983, 3 blocks).

Appendix Table B5. Analysis of variance for the transformed[a] percent number of spotted kernels among sinking (full) grains[b] in panicles of four rice lines infested with rice stink bugs (RSB) at 0, 10 and 20 days after flowering for 0, 30 and 60 bug days[c]. Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[d]	7	0.3813	3.21	0.0027
bug days	2	1.8260	53.78	0.0001
line	3	0.1631	3.20	0.0236
bug days X line	6	0.3063	3.01	0.0072
days after flowering	2	0.1956	5.76	0.0035
bug days X days after flowering	4	0.1150	1.69	0.1514
line X days after flowering	6	0.1409	1.38	0.2207
bug days X line X days after flowering	12	0.1961	0.96	0.4845
error	315	5.3478		

[a] Data were transformed by taking the arcsine square root of the % number of spotted kernels among full grains in a panicle.

[b] Grains in a panicle that sank in 9% saline solution.

[c] 0, 30 and 60 bug days represent 0 and 3 pairs of RSB adults feeding for 5 and 10 days, respectively.

[d] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 5 blocks; 1983, 3 blocks).

APPENDIX C

Appendix Table C1. Analysis of variance for the transformed[a] percent number of damaged kernels in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with adult rice stink bugs (RSB) at densities ranging from uncaged 0 to 5 pairs per panicle. Crowley, LA, 1982.

Source	df	Type III sums of squares	F value	Pr > F
block	3	0.2837	4.16	0.0067
RSB density	6	21.7798	159.81	0.0001
fungicide	1	0.5797	25.52	0.0001
RSB density X fungicide	6	0.2197	1.61	0.1440
cultivar	2	1.5155	33.36	0.0001
RSB density X cultivar	12	0.2559	0.94	0.5085
fungicide X cultivar	2	0.0341	0.75	0.4731
RSB density X fungicide X cultivar	12	0.1599	0.59	0.8524
error	260	5.9056		

[a] Data were transformed by taking the arcsine square root of the percent number of damaged kernels in a panicle.

Appendix Table C2. Analysis of variance for the transformed[a] percent number of sinking (full) grains[b] in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with adult rice stink bugs (RSB) at densities ranging from uncaged 0 to 5 pairs per panicle. Crowley, LA, 1982.

Source	df	Type III sums of squares	F value	Pr > F
block	3	0.2795	3.81	0.0107
RSB density	6	20.6860	140.96	0.0001
fungicide	1	0.5670	23.18	0.0001
RSB density X fungicide	6	0.2215	1.51	0.1753
cultivar	2	1.9802	40.48	0.0001
RSB density X cultivar	12	0.3200	1.09	0.3685
fungicide X cultivar	2	0.1015	2.07	0.1277
RSB density X fungicide X cultivar	12	0.2136	0.73	0.7239
error	260	6.3594		

[a] Data were transformed by taking the arcsine square root of the percent number of sinking grains in a panicle.

[b] Sinking grains are grains in a panicle that sank in 9% saline solution.

Appendix Table C3. Analysis of variance for the transformed[a] percent number of misclassified grains[b] in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with adult rice stink bugs at densities ranging from uncaged 0 to 5 pairs per panicle. Crowley, LA, 1982.

Source	df	Type III sums of squares	F value	Pr > F
block	3	0.0828	4.87	0.0026
RSB density	6	0.4984	14.67	0.0001
fungicide	1	0.0055	0.97	0.3256
RSB density X fungicide	6	0.0693	2.04	0.0607
cultivar	2	0.1036	9.15	0.0001
RSB density X cultivar	12	0.1479	2.18	0.0132
fungicide X cultivar	2	0.0033	0.29	0.7456
RSB density X fungicide X cultivar	12	0.0685	1.01	0.4415
error	260	1.4717		

[a] Data were transformed by taking the arcsine square root of the percent number of misclassified grains in a panicle.

[b] Misclassified grains are undamaged grains that floated and damaged grains that sank in 9% saline solution.

Appendix Table C4. Analysis of variance for the transformed[a] percent number of damaged kernels in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with 0 and 3 pairs of adult rice stink bugs (RSB). Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[b]	6	1.1689	7.07	0.0001
RSB density	1	7.5844	275.29	0.0001
fungicide	1	0.0761	2.76	0.0986
RSB density X fungicide	1	0.2152	7.81	0.0059
cultivar	2	1.2331	22.38	0.0001
RSB density X cultivar	2	0.0270	0.49	0.6139
fungicide X cultivar	2	0.0073	0.13	0.8763
RSB density X fungicide X cultivar	2	0.0169	0.31	0.7362
error	142	3.9121		

[a] Data were transformed by taking the arcsine square root of the percent number of damaged kernels in a panicle.

[b] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 4 blocks; 1983, 3 blocks).

Appendix Table C5. Analysis of variance for the transformed[a] percent number of sinking (full) grains[b] in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with 0 and 3 pairs of adult rice stink bugs (RSB). Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[c]	6	0.7530	4.54	0.0003
RSB density	1	6.8584	248.08	0.0001
fungicide	1	0.1000	3.62	0.0592
RSB density X fungicide	1	0.2959	10.70	0.0013
cultivar	2	1.5147	27.39	0.0001
RSB density X cultivar	2	0.0563	1.02	0.3636
fungicide X cultivar	2	0.0361	0.65	0.5220
RSB density X fungicide X cultivar	2	0.0068	0.12	0.8850
error	142	3.9259		

[a] Data were transformed by taking the arcsine square root of the percent number of sinking grains in a panicle.

[b] Sinking grains are the percentage of grains in a panicle that sank in 9% saline solution.

[c] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 4 blocks; 1983, 3 blocks).

Appendix Table C6. Analysis of variance for the transformed[a] percent number of misclassified grains[b] in panicles of three rice cultivars treated with the fungicide, propriconazol, and later infested with 0 and 3 pairs of adult rice stink bugs (RSB). Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[c]	6	0.2121	5.05	0.0001
RSB density	1	0.0713	10.17	0.0018
fungicide	1	0.0264	3.77	0.0542
RSB density X fungicide	1	0.0237	3.39	0.0678
cultivar	2	0.0711	5.07	0.0075
fungicide X cultivar	2	0.0101	0.72	0.4865
RSB density X cultivar	2	0.0580	4.14	0.0179
RSB density X fungicide X cultivar	2	0.0095	0.68	0.5094
error	142	0.9948		

[a] Data were transformed by taking the arcsine square root of the percent number of misclassified grains in a panicle.

[b] Misclassifed grains are undamaged grains that floated and damaged grains that sank in 9% saline solution.

[c] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 4 blocks; 1983, 3 blocks).

Appendix Table C7. Analysis of variance for the transformed[a] percent number of damaged kernels in panicles of four rice lines infested with adult rice stink bugs (RSB) at 0, 10 and 20 days after flowering for 0, 30 and 60 bug days[b]. Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[c]	7	0.3069	3.07	0.0039
bug days	2	15.5675	544.19	0.0001
line	3	0.4122	9.61	0.0001
bug days X line	6	0.1740	2.03	0.0616
days after flowering	2	6.3292	221.25	0.0001
bug days X days after flowering	4	3.8619	67.50	0.0001
line X days after flowering	6	0.2798	3.26	0.0040
bug days X line X days after flowering	12	0.3411	1.99	0.0249
error	320	4.5771		

[a] Data were transformed by taking the arcsine square root of the percent number of damaged kernels in a panicle.

[b] 0, 30 and 60 bug days represent 0 and 3 pairs of adult RSB feeding for 5 and 10 days, respectively.

[c] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 5 blocks; 1983, 3 blocks).

Appendix Table C8. Analysis of variance for the transformed[a] percent number of sinking (full) grains[b] in panicles of four rice lines infested with adult rice stink bugs (RSB) at 0, 10 and 20 days after flowering for 0, 30 and 60 bug days[c]. Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[d]	7	0.2440	2.24	0.0311
bug days	2	11.4177	366.39	0.0001
line	3	0.7602	16.26	0.0001
bug days X line	6	0.3655	3.91	0.0009
days after flowering	2	7.1192	228.45	0.0001
bug days X days after flowering	4	4.2416	68.06	0.0001
line X days after flowering	6	0.2957	3.16	0.0050
bug days X line X days after flowering	12	0.4248	2.27	0.0089
error	320	4.9860		

[a] Data were transformed by taking the arcsine square root of the percent number of sinking grains in a panicle.

[b] Sinking grains are the percentage of grains in a panicle that sank in 9% saline solution.

[c] 0, 30 and 60 bug days represent 0 and 3 pairs of adult RSB feeding for 5 and 10 days, respectively.

[d] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 5 blocks; 1983, 3 blocks).

Appendix Table C9. Analysis of variance for the transformed[a] percent number of misclassified grains[b] in panicles of four rice lines infested with adult rice stink bugs (RSB) at 0, 10 and 20 days after flowering for 0, 30 and 60 bugdays[c]. Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
year-block[d]	7	0.2471	5.46	0.0001
bug days	2	0.1075	8.31	0.0003
line	3	0.2703	13.94	0.0001
bug days X line	6	0.1912	4.93	0.0001
days after flowering	2	0.7089	54.81	0.0001
bug days X days after flowering	4	0.6848	26.48	0.0001
line X days after flowering	6	0.0833	2.15	0.0480
bug days X line X days after flowering	12	0.0980	1.26	0.2395
error	320	2.069		

[a] Data were transformed by taking the arcsine square root of the percent number of misclassified grains in a panicle.

[b] Misclassified grains are undamaged grains that floated and damaged grains that sank in 9% saline solution.

[c] 0, 30 and 60 bug days represent 0 and 3 pairs of adult RSB feeding for 5 and 10 days, respectively.

[d] Year and block were combined into a single variable because of unequal blocks for the two years (1982, 5 blocks; 1983, 3 blocks).

Appendix Table C10. Analysis of variance and nonorthogonal contrasts for the transformed[a] percent number of sinking (full) grains[b] in Starbonnet panicles infested with males, females or pairs of rice stink bugs (RSB) at densities of 0, 2, 4 and 6 insects per panicle. Crowley, LA, 1982 and 1983.

Source	df	Type III sums of squares	F value	Pr > F
RSB density	3	1.0011	66.87	0.0001
linear	1	1.3148	175.65	0.0001
quadratic	1	0.0052	0.69	0.4071
sex	2	0.1455	9.72	0.0002
female vs pairs	1	0.1334	17.82	0.0001
male vs pairs	1	0.0063	0.84	0.3625
RSB density X sex	4	0.1574	5.26	0.0008
linear density X (female vs pairs)	1	0.0902	12.04	0.0008
linear density X (male vs pairs)	1	0.0070	0.93	0.3372
quadratic density X (female vs pairs)	1	0.0001	0.02	0.8911
quadratic density X (male vs pairs)	1	0.0002	0.03	0.8586
error	95	0.5217		

[a] Data were transformed by taking the arcsine square root of the % number of sinking grains in a panicle.

[b] Grains in a panicle that sank in 9% saline solution.

APPENDIX D

Appendix Table D1. Analysis of variance of the test comparing Penn-cap M with Sevin XLR, methyl parathion and an untreated control for rice stink bug control[a] after insects were exposed to treated panicles for 24 hours. Panicles were infested with three adult pairs of field-collected rice stink bugs approximately 4, 24, 48, and 72 hours after insecticide application. Crowley, LA, 1983.

Source[b]	df	Type III SS	F value	Pr > F
Main plot				
block	2	23.15	0.00	0.9964
insecticide tmt.	3	24085.65	2.52	0.1549
block X insect. tmt. (Error A)	6	19143.52		
Sub-plot				
sex	1	7812.50	16.20	0.0038
insect. tmt. X sex	3	320.22	0.22	0.8789
block X insect. tmt. X sex (Error B)	8	3858.02		
rep(block X insect. tmt. X sex)	24	10925.92		
Sub-sub-plot				
infestation time	3	52110.34	17.66	0.0001
block X inf. time	6	4729.94	0.80	0.5816
insect. tmt X inf. time	9	44942.13	5.08	0.0017
block X insect. tmt X inf. time (Error C)	18	17708.33		
rep(block X insect. tmt. X inf. time)	72	73148.15		
sex X inf. time	3	505.40	0.50	0.6861
insect. tmt. X sex X inf. time	9	3398.92	1.11	0.3623
residual error	96	32623.46		

Appendix Table D1. Continued.

[a] ANOVA was calculated using PROC GLM (SAS 1982). Because analysis of untransformed data was almost identical to arcsine square root transformed data, results from untransformed data are reported.

[b] Pooled experimental and sampling errors within Errors B and C gave similar results as unpooled errors so errors were not pooled.

VITA

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Marieanne Hollay

Major Field: Entomology

Title of Dissertation: Rice Stink Bug, Oebalus pugnax (F.), on Rice: Evaluation for Plant Resistance, Interaction of Field Fungi With Feeding Damage, and Evaluation of Insecticides for Control

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